AD-A198 978

DTIC FILE COPY

(4)

Technical Document 1278
May 1988

Instrumentation For Undersea Visibility Monitoring

Biospherical Instruments Inc.

Approved for public release; distribution is unlimited.

The views and conclusions contained in this report are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Naval Ocean Systems Center or the U.S. Government.

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152-5000

E. G. SCHWEIZER, CAPT, USN
Commander

R. M. HILLYER
Technical Director

ADMINISTRATIVE INFORMATION

This document was prepared by Biospherical Instruments, Inc. for Code 0141 of the Naval Ocean Systems Center.

Released by
R. November, Head
Industry R&D Programs
Office

Under authority of
J. Silva, Head
Program Director for
Technology

JJ

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) N87-238	5. MONITORING ORGANIZATION REPORT NUMBER(S) NOSC TD 1278
6a. NAME OF PERFORMING ORGANIZATION Biospherical Instruments, Inc. 6b. OFFICE SYMBOL (if applicable)	7a. NAME OF MONITORING ORGANIZATION Naval Ocean Systems Center
6c. ADDRESS (City, State and ZIP Code) 4901 Morena Blvd. Suite 1003 San Diego, CA 92117	7b. ADDRESS (City, State and ZIP Code) San Diego, CA 92152-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Sea Systems Command 8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N66001-87-C-0416
8c. ADDRESS (City, State and ZIP Code) Washington, DC 20362	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	AGENCY ACCESSION NO.
65502N	XB26	S1814	DN305 182

11. TITLE (Include Security Classification)

INSTRUMENTATION FOR UNDERSEA VISIBILITY MONITORING

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Oct 1987 TO Jan 1988	May 1988	83

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	photodetectors irradiance transmissometer

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Navy, in its issuance of the 1987 SBIR Call for Proposals, identified a need for an "Undersea Visibility Condition Monitor." This solicitation describes the necessity for a highly portable system to survey visibility at relatively low light levels. Biospherical Instruments responded to this call and received a contract for the first phase of this development effort. This is the Final Report of the Phase One effort to develop this monitoring system.

The main objective of the Phase I effort was to provide a working prototype of the visibility monitoring system that was operational from a "Boston Whaler" type vessel. An outline of this system is presented ~~in Figure 1~~. ~~We felt that~~ the primary objective in Phase I was to get a fully operational system in the hands of Navy scientists in order to prove the principles of the design and to use the Phase II effort primarily for refinements. Biospherical Instruments feels that this objective was met.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL R. November, COTR	22b. TELEPHONE (Include Area Code) (619) 553-2103 22c. OFFICE SYMBOL Code 0141

DD FORM 1473, 84 JAN

83 APR EDITION MAY BE USED UNTIL EXHAUSTED
ALL OTHER EDITIONS ARE OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

Biospherical Instruments Inc.

DEFENSE SMALL BUSINESS INNOVATIONAL RESEARCH (SBIR) PROGRAM

TOPIC NUMBER N87-238

FINAL REPORT: PHASE I

INSTRUMENTATION FOR UNDERSEA VISIBILITY MONITORING

SUBMITTED BY: BIOSPHERICAL INSTRUMENTS INC
4901 MORENA BLVD.
SUITE 1003
SAN DIEGO, CA 92117

SUBMITTED TO: COMMANDER
NAVAL OCEAN SYSTEMS CENTER
CODE: 222
271 CATALINA BOULEVARD
SAN DIEGO, CA 92152

Introduction

The Navy, in its issuance of the 1987 SBIR Call for Proposals, identified a need for an "Undersea Visibility Condition Monitor". This solicitation describes the necessity for a highly portable system to survey visibility at relatively low light levels. Biospherical Instruments responded to this call and received a contract for the first phase of this development effort. This is the Final Report of the Phase One effort to develop this monitoring system.

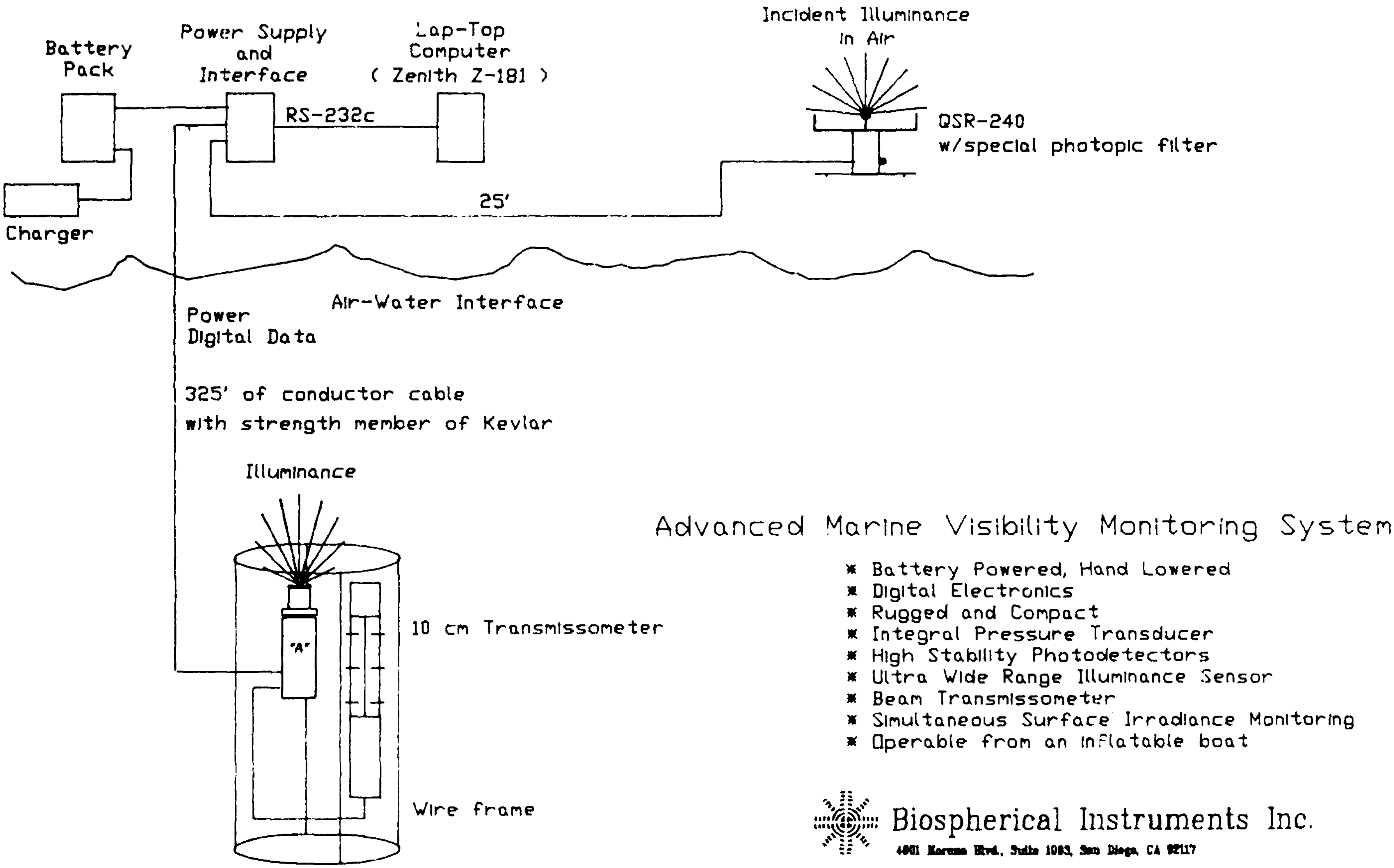
The main objective of the Phase I effort was to provide a working prototype of the visibility monitoring system that was operational from a "Boston Whaler" type vessel. An outline of this system is presented in Figure 1. We felt that the primary objective in Phase I was to get a fully operational system in the hands of Navy scientists in order to prove the principles of the design and to use the Phase II effort primarily for refinements. Biospherical Instruments feels that this objective was met.

Approach to the Problem

The first stage of the Phase One project involved selecting an underwater testing various photodetectors for use in the high sensitivity photometric detector. This selection led us to select a large area silicon detector in combination with a photopic correction filter. This combination yielded a system noise level near 10^-6 foot-candles; the design goal. This detector will then have a maximum irradiance level of approximately 1 foot-candle. In order to have the system work in full sunlight, which we feel is necessary to understand the optical media being studied, we incorporated a second, lower sensitivity detector-filter combination to extend the working range of the system to 20,000 foot-candles.

In addition to these two detectors, we integrated into the system a beam transmissometer. A surface illuminance sensor has also been fabricated and integrated. This sensor will monitor solar illuminance above water while a vertical profile of submarine irradiance is recorded. This sensor was modeled after our QSR-240 Scalar Irradiance Meter thus giving a directional response that is hemispherical. It is felt that in very small boats, considerable motion caused by waves will introduce less variation into this type of sensor as compared to a "flat plate" illuminance sensor. Additional parameters measured include the depth of the underwater sensor package, and the voltage of the batteries supplying power to the system. A detailed description of this system may be found in the Instruction Manual written to accompany the instrument (See Appendix 1).

FIGURE 1


Battery Pack
Power Supply and Interface
Lap-Top Computer (Zenith Z-181)
RS-232c
Charger
25'
Incident Illuminance In Air
QSR-240
w/special photopic filter
Air-Water Interface
Power
Digital Data
325' of conductor cable
with strength member of Kevlar
Illuminance
"A"
10 cm Transmissometer
Wire frame
Advanced Marine Visibility Monitoring System
* Battery Powered, Hand Lowered
* Digital Electronics
* Rugged and Compact
* Integral Pressure Transducer
* High Stability Photodetectors
* Ultra Wide Range Illuminance Sensor
* Beam Transmissometer
* Simultaneous Surface Irradiance Monitoring
* Operable from an inflatable boat
Biospherical Instruments Inc.

The signals from all of the system sensors are digitized and transmitted up the underwater cable to the surface. At the surface a battery powered "laptop" computer is used to receive these data, display them numerically on the LCD screen of the computer, and store the results on disk.

The battery powered "laptop" computer selected was the Zenith Z181 because the Navy has in-house service facilities for this brand. Preliminary software programs have been written for the data acquisition during the vertical profiles. This software acquires separate data sets during the up and down casts along with calibration data. The data was averaged into nominal 1 foot deep bins and written to disk in "ASCII comma separated format" at the end of the up cast segment. Numerical display of the measured parameters occur during the cast.

Analysis of the recorded data was done on shore by the contract monitor using the computer program "Lotus 1-2-3". The drawbacks of having to return to shore for data analysis will be addressed in the proposal for Phase Two work.

Results of Field Testing

The completed system was delivered to Mr. Al Lewis for field testing in January 1988. During the period of January 25 to February 4, 1988, the system was used in support of Navy projects. After that testing the system was returned to Biospherical Instruments for recalibration and further testing. A set of data acquired by Mr. Lewis was also included.

The software delivered for the testing was written in such a way as to prompt the user to make certain tests prior to conducting a vertical profile. The purpose of these tests was to ascertain the stability and calibration of the sensors. These tests instructed the user to cover the sensors and then to press a key on the computer. The user was also instructed to clean the windows of the transmissometer and to block the beam for full scale and zero readings respectively. A summary of these data taken during the Navy testing is presented in Table I.

TABLE I: Summary of Surface Corrections for G0-400 Visibility Profiling

First field tests: Jan 25 to Feb 4, 1988

Data File	Light 1 Dark	Light 2 Dark	Transmissometer Blocked	Transmissometer Clear
P012588B BND	-.000090	.000003	-.001710	3.686523
P012588A BND	-.001961	.000005		.000251
P012588C BND	-.000090	.000003	-.001710	3.686523
P012588D BND	-.000100	.000030	.000091	4.568848
P012688A BND	-.000051	.000056	.000309	4.603027
P012688B BND	.000055	.000144		1.574951
P012688C BND	-.000031	.000124	-.003467	3.644775
P012788A BND	.000034	.000114	.000351	4.422119
P012788B BND	-.178497	.000044	.000288	4.037109
P012788C BND	-.005342	.000048	.000258	3.601074
P012788D BND	-.000103	.000016	-.000104	3.182373
P012888A BND	-.000062	.000032	-.000226	3.756348
P012888B BND	-.041231	.000081	-.003996	4.262939
P012988A BND	-.000562	.000001	.000274	3.307617
P020188A BND	-.233877	.000051	-.001665	4.087891
P020188B BND	-.131730	.000094	.000422	2.227524
P020288A BND	-.050208	.000091	.000265	3.056313
P020388A BND	-.000011	.000111	.000317	3.960022
P020388B BND	-.000154	.000113	.000157	4.015400
P020388C BND	-.025268	.000100	-.001850	1.469772
P020488A BND	-.000056	.000074	.000216	4.269775
P020488B BND	-.047776	.000116	.000359	4.589844
P020488C BND	-.204775	.000079	.000362	4.597412
P020488D BND	-.078050	.000095	.000694	4.355469
P020488E BND	-.071946	.000077	-.000078	3.802734
P020488F BND	-.094502	.000069	.000461	3.897949
P020488G BND	-.000774	.000047	.000201	2.488525
P020488H BND	-.080123	.000031	-.000176	3.567627

Inspection of these data indicate that the user was successful in blocking the transmissometer beam and that the signal with the beam blocked ranged over an interval of less than 2 millivolts. This translates to a range in beam transmission of much less than one percent. On the other hand, the full scale readings (beam unblocked) ranged from 4.68 Volts to a low of 1.46 Volts (ignoring one instance where the beam must have been mistakenly blocked). This is a considerably large range and indicates that either the system as a whole was not working well, or that the windows of the transmissometer had water drops or water spots on them causing the large decrease in the reading. The worst data file, P020388C.BND was inspected and showed that as soon as the sensor was put in the water the readings returned to a normal "clean water" value and did not show similar values for the rest of the profile. We assume from this that it was either not possible to keep the windows clean in field use or other factors such as very wet conditions or time constraints prevented their careful cleaning. A similar inspection of the sensor dark values indicate, particularly in the case of the more sensitive sensor, that it was not possible to truly get the sensors dark. This is understandable since in the case of the most sensitive sensor, one one-millionth of a percent of full sunlight will cause a reading of many millivolts. In order for these readings to be taken reliably in the future, we will need to provide a protective and truly light-tight cap to be deployed over the sensor prior to use. Tranmissometer calibration will be restricted to a monthly calibration schedule where more careful cleaning is possible.

Inspection of the data files returned from the Navy testing revealed that the bin averaging technique combined with the microprocessor circuitry in the sensor assembly resulted in some depth increments not being sampled. In the Phase II effort we plan to increase the sampling rate by approximately a factor of two which should eliminate this problem when the probe is lowered at a normal rate.

While the normal data acquisition program used during the Navy tests generated data in one foot deep "bins", in our field testing we used a program that acquired data and recorded every sample separately. Results from a profile taken in the ocean off of Scripps Institution of Oceanography in La Jolla is presented in Figures 2, 3 and 4. Figure 2 shows a vertical profile of beam transmission while Figure 3 is of illuminance. Figure 4 is a vertical profile of temperature taken the same morning but with a different system. In the profile of illuminance, all three light sensors are plotted after the log of the signals are computed. This allows all of the signals to be displayed on the same scale. This profile was recorded in relatively "green" ocean water one day after a winter storm. Only at the deepest extent of the profile was the most sensitive light sensor within its normal operating range. It is also possible to notice a slight offset between the low and high sensitivity sensors. This is due to a calibration error and will be corrected in the Phase II effort. The recording of the surface irradiance is also presented in this Figure. The recording of temperature versus depth is on a different scale (meters).

Following the tests by the Navy between 1/25/88 and 2/4/88 a recalibration of all of the sensors was performed at Biospherical Instruments. The results from this calibration indicated that significant changes occurred in the absolute calibration some of the sensors. Specifically, the low level light sensor changed by -13.7%, the high light level sensor changed by 24.9% and the surface sensor by 29%. Small (<100 microvolts) changes in the zero values were also recorded. These changes could have resulted from a variety of factors. These factors include error in the original calibration due to improper standards or application of those standards, changes in the sensors due to mechanical alignment changes in the filter and detector assembly, in changes in the material used

FIGURE 2

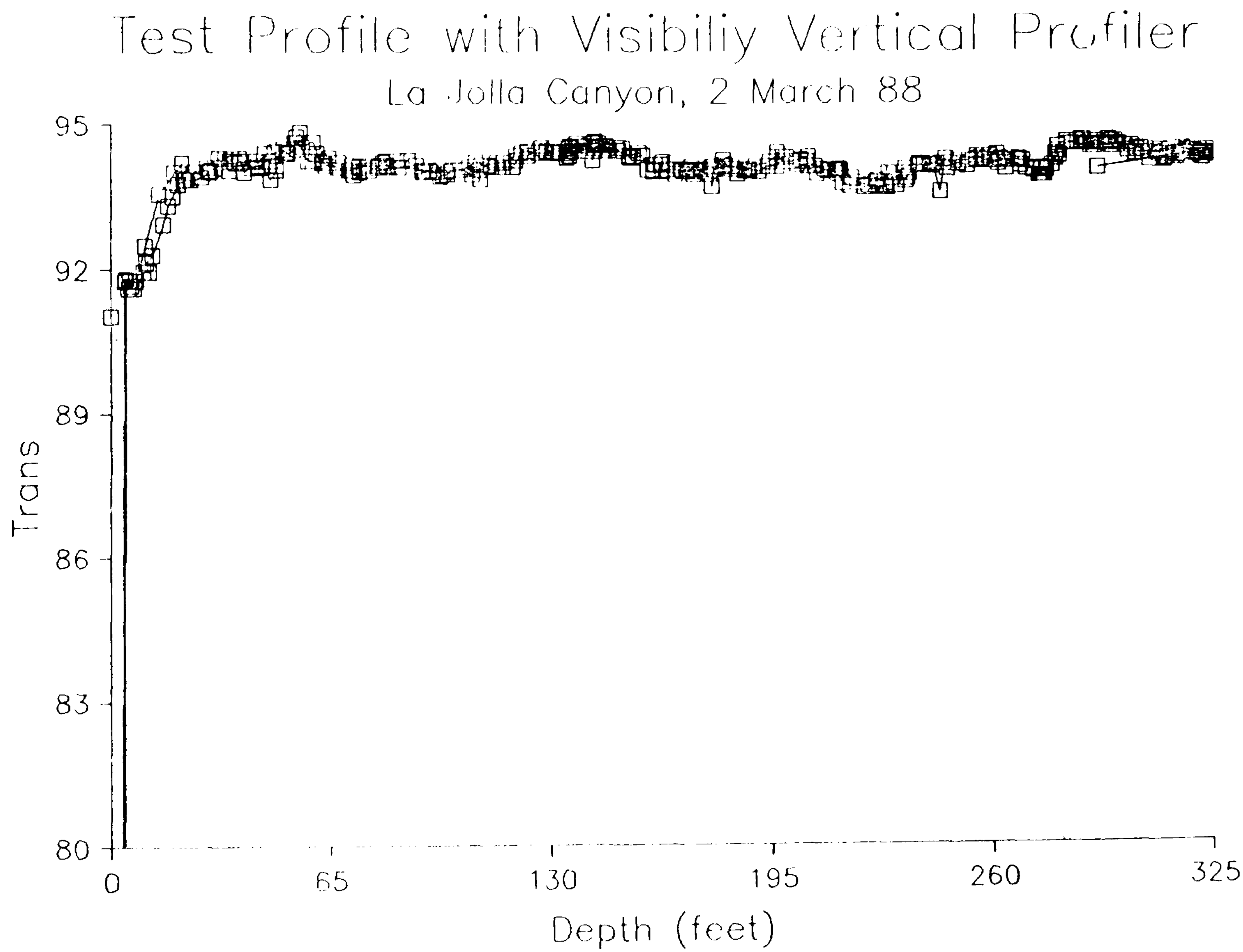

Test Profile with Visibiliy Vertical Profiler
La Jolla Canyon, 2 March 88
95
92
89
86
83
80
Trans
0
65
130
195
260
325
Depth (feet)

FIGURE 3

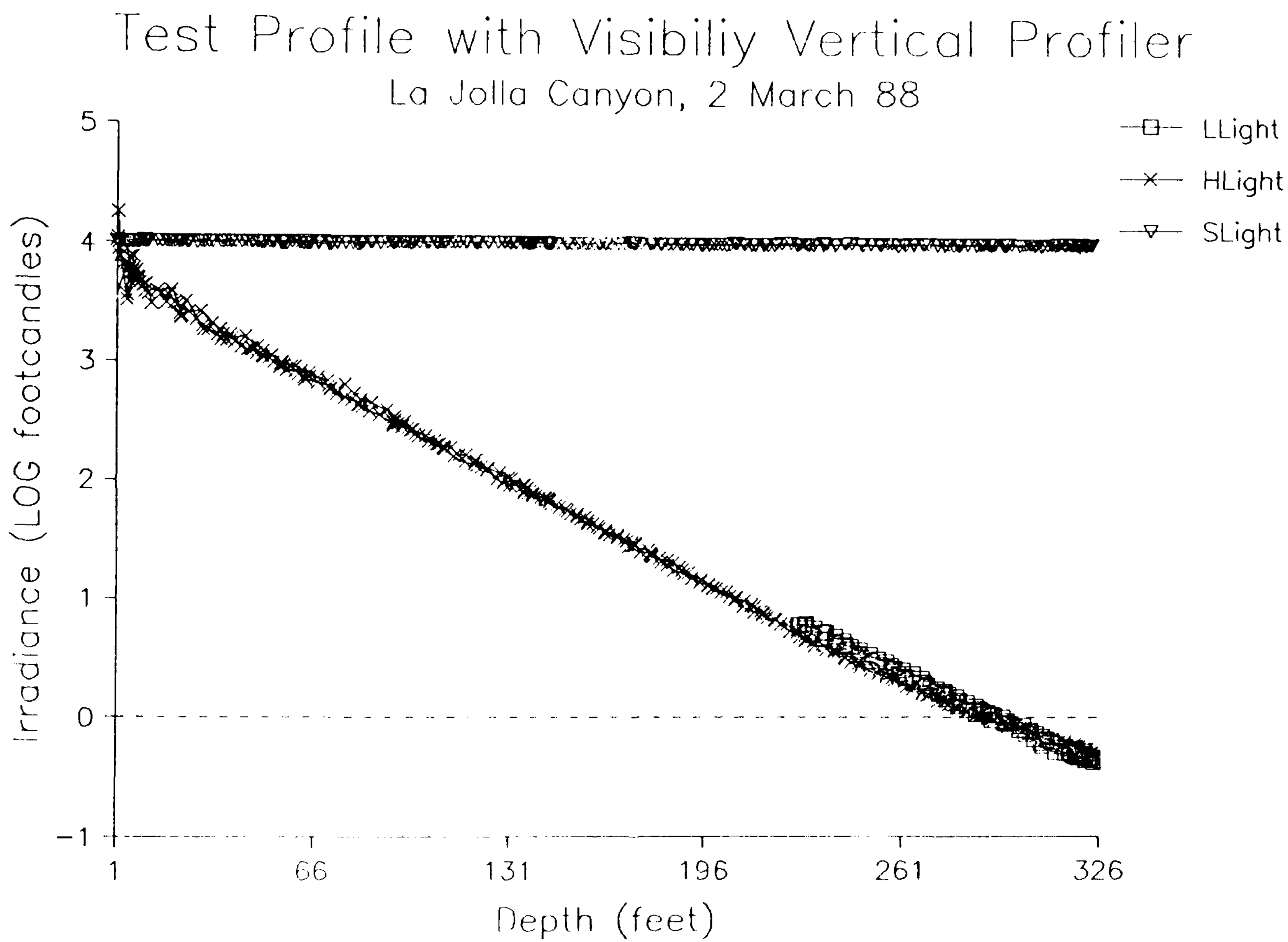
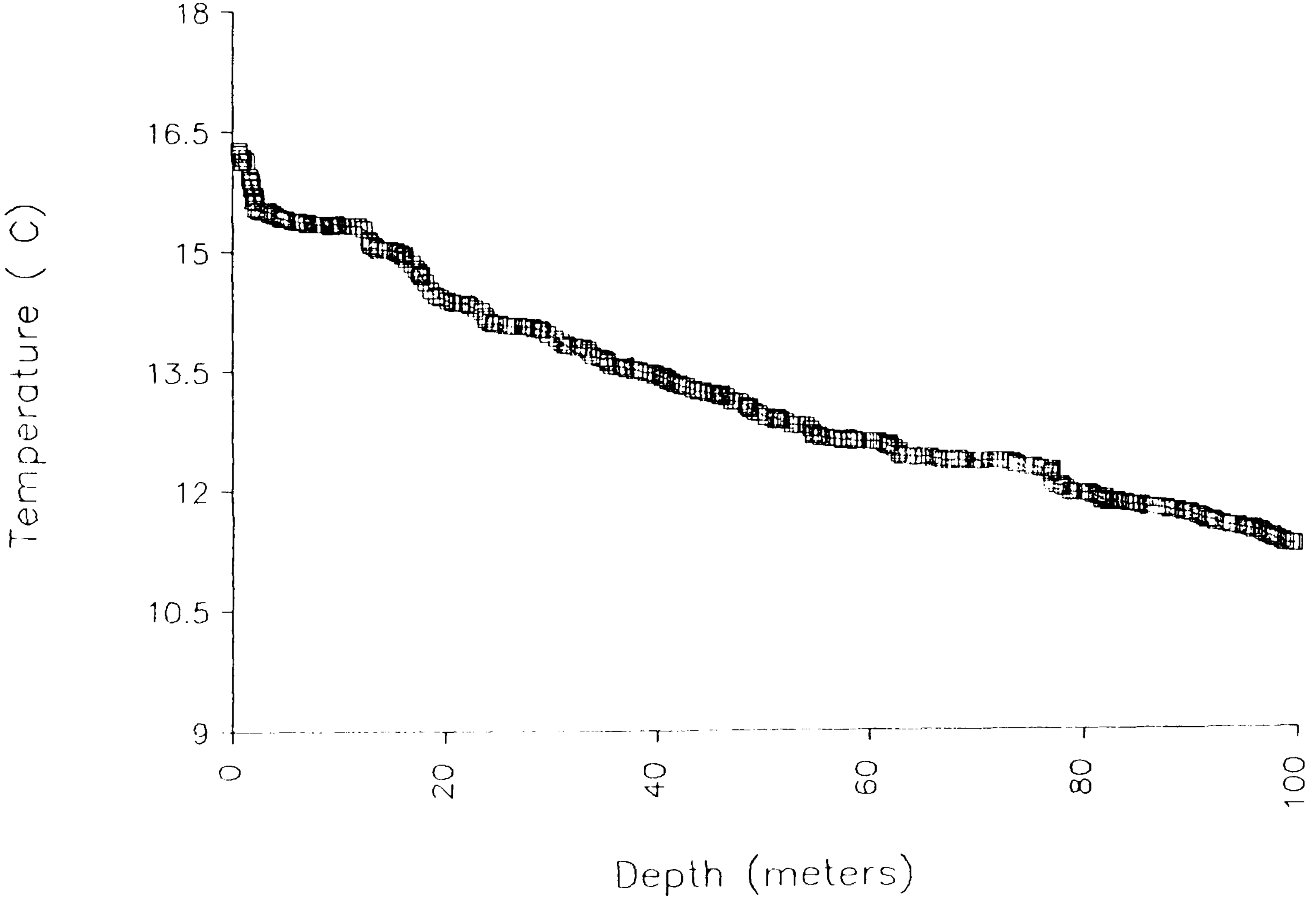

Test Profile with Visibiliy Vertical Profiler
La Jolla Canyon, 2 March 88
Irradiance (LOG footcandles)
Depth (feet)
LLight
HLight
SLight
5
4
3
2
1
0
-1
1
66
131
196
261
326

FIGURE 4

Natural Fluorometer #1 Field Test 3 March 88

Temperature Profile



in the diffuser, and changes the various components due to temperature changes.

We have looked at the various possibilities and feel that the calibration of this sensor must be tracked and recalibrated frequently. We also feel that we must take additional steps to secure calibration standards for photometric measurements to supplement our radiometric standards. It should be pointed out that we used National Bureau of Standards calibrated **Standards of Spectral Irradiance** and calibrated detectors obtained from other companies to do the photometric calibration. This procedure should be changed to obtain NBS photometric standards for direct calibration. It also needs to be mentioned that such standards exist (to our knowledge) only at light levels above 50 foot-candles, a factor of almost 100 above the maximum allowed range for the low light level sensor. In order to accommodate existing photometric standards at levels below 1 foot-candle, we will have to fabricate longer optical benches in the Phase Two effort.

Further testing during the Phase II effort will include temperature testing to determine the temperature response of the entire system under the full anticipated temperature range (0 to 35 degrees C). It is possible that we may have to incorporate temperature compensation elements into the circuitry, but this, if necessary, should be accommodated by the data acquisition already designed and tested in the Phase I version. A calibration stability of ±5% per year would be considered reasonable.

Anticipated Phase II Follow-on

Near the end of the Phase One effort the prototype was delivered to the Navy scientists (including Mr. Al Lewis) for field testing. After this testing a number of findings were reported to us. A summary of our understanding of these findings is presented below.

1 The sensor package performed satisfactorily. The size and packaging of the underwater components was satisfactory with the possible exception of the size (length) of the transmissometer component.

2 The presence of the personal computer, with exposed keyboard and disk drives was felt to decrease the ability of the system to operate under rough field conditions.

3 A simple, simultaneous read-out of the parameters under study (depth, light, transmission) was desirable.

4 A "graphic" profile display of the vertical structure of these parameters would be a nice feature. This would

permit the personnel to see a "picture" of the turbidity as a function of depth displayed while the profile is being conducted.

5 The simplest possible controls are desired. Perhaps "On/Off", "Start Profile", "End Profile" switches as the only controls.

6 The inclusion of water temperature as a measured parameter would be desirable.

In considering these options we have chosen to add several possibilities for additional capabilities. These are:

7 The ability to store, in full detail, several profiles in the internal memory of the surface display unit. This would enable the operator to take the surface display unit back to his office or laboratory, and dump these data into his personal computer for addition to a data base. Data would be dumped using the RS-232 serial data link found on most personal computers.

8 A small printer (approximately the size of a paperback book) could be added to the deck box. This could dump a graphic plotted profile out on command while still on the small boat. This would permit sharing of this "hard copy" of the vertical visibility profile with other interested parties. This would be inside the deck box and, on command, would operate a printout.

9 The a full documentation package for the resulting system should be generated. It is anticipated that in addition to a complete instruction manual, this package will include detailed drawings and diagrams for field trouble shooting and service. We would also work with Naval personnel for the development of spare parts kits and other support materials including field training, if necessary.

10 Field testing revealed a discontinuity in the transition from the high light sensor to the low light sensor and calibration drift. It is suspected that this is caused by the slightly different spectral response of the two sensors. We will correct these in the second prototype.

We agree with the findings and want to add that the calibration and stability of the system need to be further investigated.

In summary, the goal of a Phase II effort should be to provide the most rugged field instrument possible combined with simplicity of operation and stability of calibration. This goal will involve additional field testing of the Phase I prototype with Naval personnel, particularly including repeated calibrations, analysis of the collected data, and then arrival at mutually agreeable final design modifications. After the final prototype is built additional testing will occur. During this phase, Biospherical Instruments should participate in the field testing activities.

Biospherical Instruments assumes that these Phase II systems will be built to our highest standards of reliability, but they will not need to meet any particular military specification standards. It would be possible for us to meet those standards, but the proposal amounts intended to be requested for the Phase II effort will have to be modified for this requirement is made.

APPENDIX 1

OPERATION MANUAL

PHOTOMETRIC VERTICAL PROFILER-400
PVP-400

TABLE OF CONTENTS

I SYSTEM DESCRIPTION

A. PURPOSE OF SYSTEM

The PVP-400 system is an underwater measurement device which gives simultaneous measurements of light levels, both above and below the water, depth underwater and the transmissivity of the water. It is designed to be used in ocean environments at depths of up to two hundred meters. The system can measure visible light intensity over a wide dynamic range.

Designed to interface directly to a personal computer via a standard RS-232 serial link, the PVP-400 allows the user to store and process data in a variety of ways. Data acquisition software is supplied for an IBM compatible personal computer, allowing information to be stored on disk in text files.

B. SYSTEM COMPONENTS

The Logging Computer

Supplied with the PVP-400 system is a Zenith Z181 laptop computer. It has a serial port and software allowing it to be used as the logging computer for the system. The output from this software, text files stored to disk, will be directly usable with several spreadsheet packages for IBM PC compatible computers.

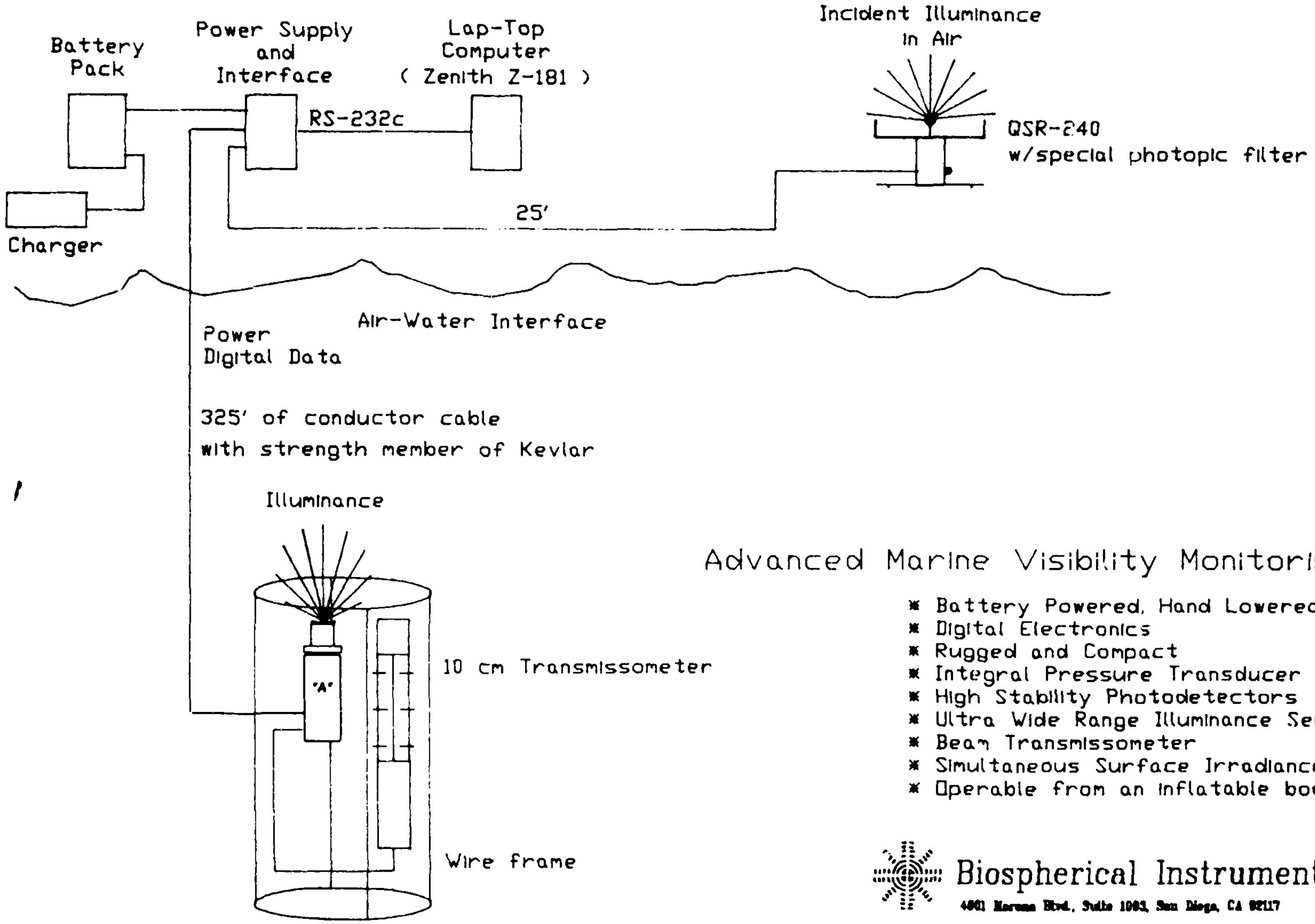
The PVP-400 communicates with the computer using a two-wire RS-232 serial link. Thus any computer capable of receiving such a serial signal and translating the PVP-400's data format code could be used as the logging computer.

The Deck Box

The deck box for the PVP-400 system is used to interface all other system components, including the instrumentation unit, surface light sensor, battery and the logging computer. The deck box contains the master power switch for the PVP-400 system, a 'Power' indicator LED and a 'Serial Link' LED showing RS-232 activity. In normal operation the 'Power' LED will remain lit and the serial link LED will pulse at regular intervals. Each connector on the deck box is different from all others. Also, each connector is keyed, which simplifies the interconnection of cables in the system.

The Instrumentation Unit

The instrumentation unit is actually two separate devices, the Biospherical Instruments PVP-400 underwater measurement unit and a ten centimeter transmissometer manufactured by Sea Tech, Inc. These two units are mounted in a metal frame and connected by a short underwater cable. The underwater measurement unit contains the analog/digital converter which



Advanced Marine Visibility Monitoring System

* Battery Powered, Hand Lowered
* Digital Electronics
* Rugged and Compact
* Integral Pressure Transducer
* High Stability Photodetectors
* Ultra Wide Range Illuminance Sensor
* Beam Transmissometer
* Simultaneous Surface Irradiance Monitoring
* Operable from an inflatable boat

Biospherical Instruments Inc.
4901 Morena Blvd., Suite 1003, San Diego, CA 92117

digitizes measurement voltages and the CPU which transmits the digital data to the deck box on the surface.

The housings in the instrumentation unit are made of Acetal, a plastic material that will not corrode in ocean water. The unit is suspended underwater from a reinforced marine cable which supports the metal frame via a harness clamped to the cable. There are two 4-Pin connectors on the PVP-300 measurement unit; the bottom one connects to the transmissometer, and the top one connects to the deck box by a one or two hundred meter cable.

The Surface Light Sensor

The surface light sensor measures the intensity of visible light at the surface of the water. It is designed to be used on deck and is splash resistant, but not waterproof. Be careful about casting shadows on this sensor. This sensor connects to the deck box through a marine cable.

Cables

There are four cables in the PVP-400 system. They are:

1 The Transmissometer cable (underwater cable connecting the transmissometer to the G0300 underwater measurement unit).

2 The Instrumentation Unit cable (reinforced underwater cable connecting the instrumentation unit to the deck box).

3 The Surface Light cable (marine cable connecting the Surface Light sensor the the deck box).

4 The Logging Computer cable (RS-232 cable connecting the deck box to the logging computer).

II SYSTEM OPERATION AND CAUTIONS

A. BASIC SYSTEM MAINTENANCE

The PVP-400 system is a delicate electronic instrument and should be handled with care; especially the transmissometer and underwater sensor units. Make sure that cables are not crushed or bent sharply. A frequent cause of system failure is the breakage of conductors within the cables. This is usually due to the cables being bent at the connector attachment. Take care attaching and removing the cables and do not rest any unit (within the system) with its connectors facing down.

Clean the underwater unit, transmissometer, surface light sensor and cables with fresh water after use. **Do not let the logging computer or the deck box get wet--they are not waterproof.** Also, avoid getting the connectors on the ends of the cables wet as this could cause them to corrode or tarnish.

Sunlight causes plastic to age more quickly; **store the system out of the sunlight.** This will help prevent premature cracking of cable insulation and deterioration of plastic housings. Also, the logging computer must be kept dry and out of salt spray at all times.

Inspect connectors before and after each use. Forcing a connector with a bent pin into its mating socket could cause a short circuit and costly damage to the system.

B. USING THE BATTERIES

There are two separate batteries in the system. One battery is for the main system power, and the other is an internal battery to the Zenith Z181 logging computer. These two batteries are designed to be used in different ways.

The main power battery for the PVP-400 system is connected directly to the deck box. It should be charged as often as possible, by disconnecting it from the deck box and connecting it to the wall-mounted charger supplied with the system. This battery is not 'deep cycle' and should not be allowed to run down very far. You can leave this battery charging up to 24 hours without hurting it. This battery will power the system properly as long as its output voltage is greater than 8 Volts. You can read this voltage on the screen of the logging computer, in the "Battery Voltage" column when the system is operating.

The battery inside the Zenith Z181 computer is designed to be run until it is discharged. **DO NOT leave the computer hooked to its charger for more than 12 hours.** This will shorten the life of the battery. Even when you are using the computer, the battery is still charging. **Do not leave the computer plugged into its adapter for long periods of time, even if the is computer turned on.** Run the computer until its red 'LOW POWER' indicator flashes. This should take approximately 3 hours. At this time you should charge the computer's battery for no more than 12 hours.

C. STARTING THE SYSTEM

After setting up the PVP-400 system, turn on the power switch located on the deck box. The 'Power' LED should light up and remain lit. After a few moments the 'Serial Link' LED should start pulsing at regular intervals. If neither LED lights up, check the battery cable connections. Your battery may be in need of recharging. If the Serial Link LED is not active, then check the cable connecting the deck box to the underwater instrumentation unit.

Starting the Logging Computer

The logging computer supplied with the PVP-400 system (Zenith Z181 Laptop Model) is an IBM compatible PC running IBM DOS. The program disks included with the computer are set up so that the PVP-400 operating software will start automatically.

With the PVP-400 system operating and the RS-232 cable connected between the deck box and the logging computer, turn the logging computer on (the power switch for the Zenith Z181 is a slide switch on the right hand side of the computer). As soon as you have turned the computer on, put the PVP-400 program disk in the 'A:' drive (for the Z181, this is the left drive, which you open by sliding its latch back and releasing). Close the disk drive. The computer should 'Boot Up' and automatically run the data acquisition program.

If you do not see the Biospherical Instruments start up screen, then check to make sure you have the correct disk in the 'A:' drive and, if so, try using a different copy of the program disk. **NOTE: Always keep at least two extra copies of the program disk around.** Disks have been known to fail or get lost at some of the worst times.

If the computer starts the PVP-400 software properly, the computer will display the filenames in which it will store the session data. These two filenames will consist of the letter 'P' followed by the current date, followed by a single letter. If this is not your first session of the day the letter allows a unique name to be assigned to each of 26 different sets of data taken on any one day. This is followed by the characters '.BND' or the characters '.BNU'. The filename with a suffix of '.BND' will hold the data for the downcast, while '.BNU' holds the data for the upcast.

You may either accept these file names or change them to any valid file names you want. To accept these default names, press 'Return'. **To enter new file names**, type 'N' and then hit return. The program will prompt you to enter new names for the files.

D. TAKING 'ZERO' READINGS

Once you have selected the file names, the program will ask you to take "Zero' measurements for several of the sensors. These readings are recorded with the upcast and downcast data for use in calibrating the instruments. Follow the instructions on the computer screen. **NOTE:** When the computer prompts you to cover the light sensors on top of the PVP-400, you must cover them with a completely opaque object (such as a flat piece of thick black plastic). **A black rag or your hand is NOT sufficient; the low light sensor on top of the underwater measurement unit is very sensitive. It can see through your hand and will register an incorrect zero reading.**

E. THE DOWNCAST

When you have completed the zero readings, the computer will prompt you to prepare for the downcast segment. When you have prepared the unit for lowering, press 'Enter' on the keyboard. The computer will begin reading the measurements from the PVP-400 and display them on the computer screen in a table format. Columns of data for the depth of the measurement unit, battery voltage, transmissivity of the water and surface light will display. Additionally, the computer will store this data in its memory as a Table of Parameters Versus Depth. Multiple readings at any depth are averaged together to yield a composite value for that depth.

When you have finished the downcast, press the 'F9' special function key on the keyboard. The computer will beep and write its data to the disk drive in the upcast data file. It will then prompt you to press 'Enter' to begin the upcast.

F. THE UPCAST

With the message "Press enter to begin upcast" displayed on the computer screen, Z181 waits to start recording upcast data. After you press 'Enter', the computer will again display and store data received from the underwater measurement unit, just as it did for the downcast. The only difference is that when you press the 'F9' key to end the upcast, the data will be stored in the upcast file instead of the downcast file.

When you finish the upcast, press the 'F9' key. The computer will write the upcast data file to the disk and will then ask you whether you wish to retain this data or not. If the data is good and you want to keep it, press 'Enter'. However, if something went wrong with this session and you can't use the data, then you may get rid of it by typing "ABORT" before you press enter.

The program will now end, advising you to turn off both the PVP-400 system (at the deck box) and the computer itself.

If you should need to restart the PVP-400 software without turning the computer off and on again, you may do so by typing "PROFZ8" when you see the 'A>' prompt (DOS prompt) on the computer screen.

The PVP-400 system is designed to be used in a marine environment. However, the Z181 computer is not. It is a delicate device which can be ruined by salt spray and prolonged exposure to sunlight. **Keep the computer protected as much as possible.** Also, **do not leave the floppy disks lying out in the open; sunlight and moisture will ruin them.** Keep disks sealed in a plastic bag, or something watertight, when they are not being used.

III SYSTEM TECHNICAL OVERVIEW

The PVP-400 is a data acquisition system designed for accurate measurement of underwater light levels over a wide dynamic range, at a depth of up to 200 meters. The system simultaneously records data for light levels and transmissivity; the depth corresponding to those measurements and light levels at the water's surface. The system is designed to interface with an IBM compatible personal computer through an RS-232 serial port. A Zenith Z181 laptop computer, used as the logging computer, is supplied with the system. Its software saves data in text files on 3.5 inch disks. These data can be processed by a variety of methods including spreadsheet programs.

A. System Hardware

The PVP-400 system is divided into four sections: the instrumentation unit, deck box, surface light sensor and the logging computer. The instrumentation unit contains the system controller, underwater light sensors and pressure (depth) sensor, as well as the transmissometer (in a separate housing).

The instrumentation unit contains the analog/digital converter which digitizes all sensor measurements for transmission to the logging computer. The deck box is the interface unit which connects all the other system parts together. The surface light remote sensor is connected to the deck box by a long cable. This allows the sensor to be moved away from obstructions which might cast shadows or reflections on the unit. The portable logging computer is equipped with an RS-232 serial port which is connected to the deck box. It is used to decode the PVP-400 encoded digital output and write the data to text files on disk.

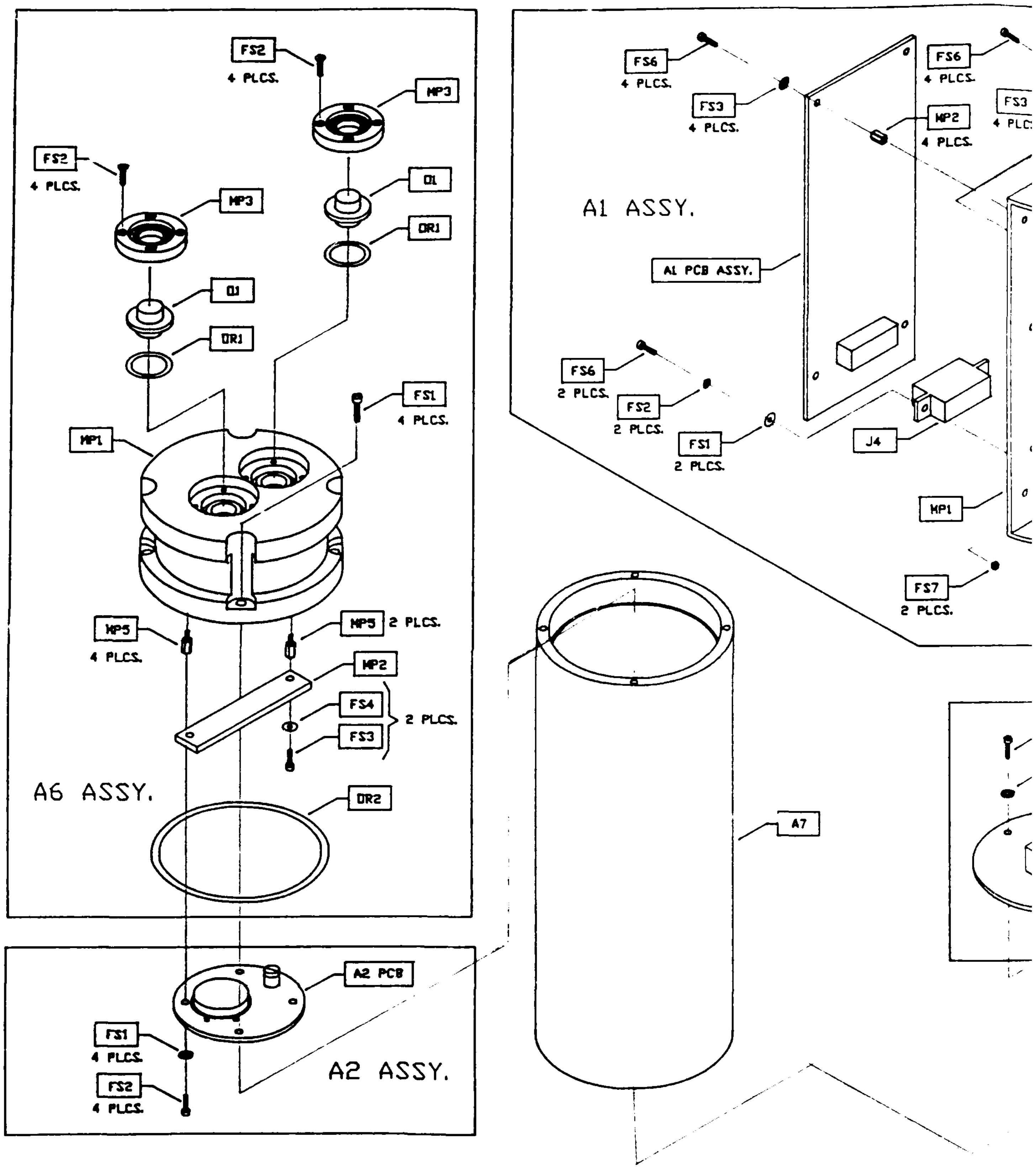
B. The Instrumentation Unit

The instrumentation unit consists of two subsystems mounted in a metal frame. The first subsystem is the Biospherical Instruments PVP-400 underwater measurement unit which contains the system controller, underwater power supply and regulation circuitry, in addition to the analog/digital converter and the low light/high light sensor circuitry. The second subsystem is a 10cm transmissometer manufactured by Sea Tech, Inc.

The system Controller is a CMOS version of the Z8 microcontroller. The A/D conversion circuitry consists of an eight channel analog multiplexer followed by a programmable gain amplifier which feeds a twelve bit A/D converter (with polarity, 13 effective bits). The eight channels measured by this circuitry are:

1 Depth sensor
2 Low light sensor
3 Battery voltage
4 Transmissometer output
5 High light sensor
6 Surface light sensor
7 Ground voltage
8 +5V supply voltage

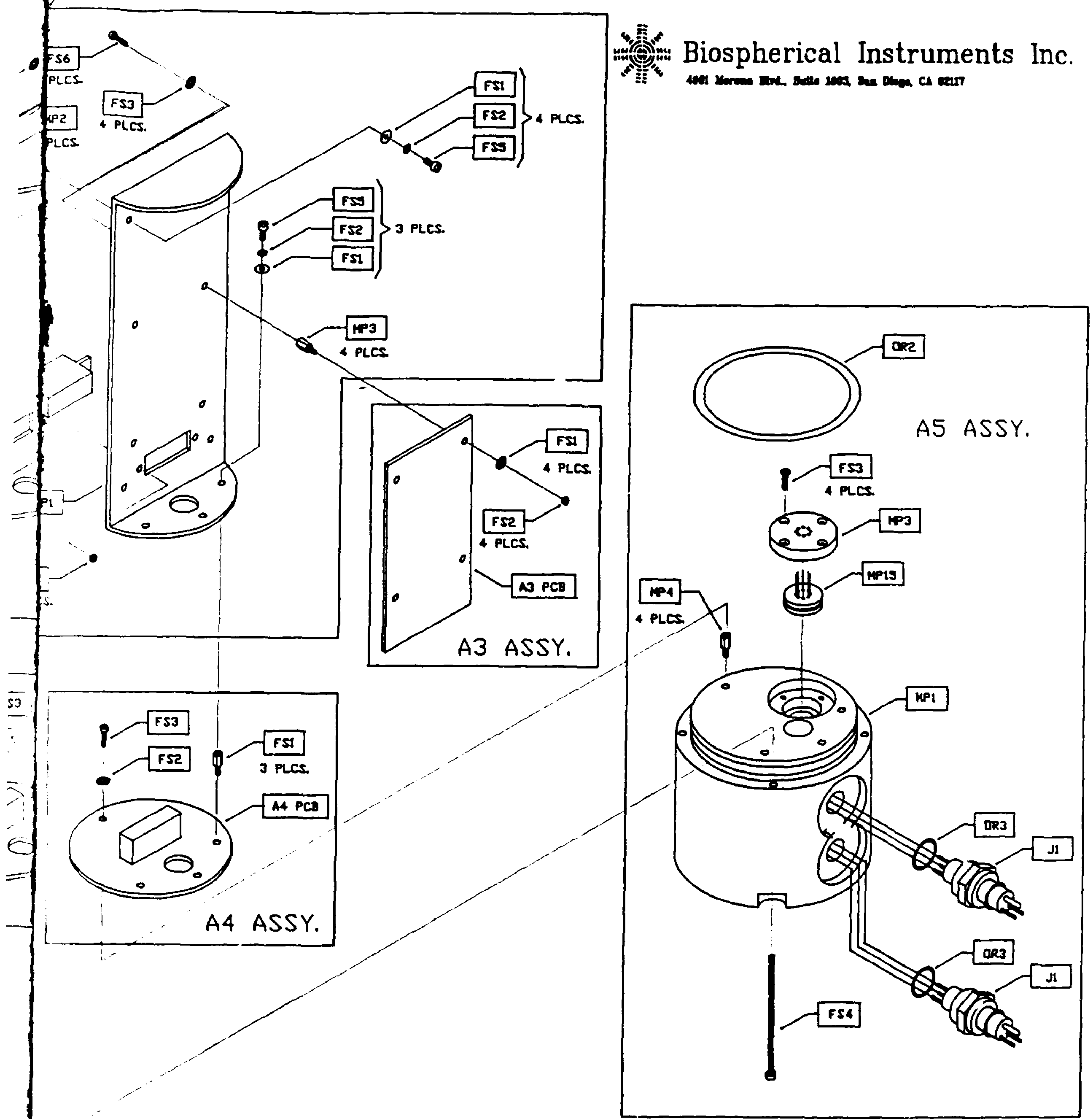
This is also the order in which the channels are recorded to disk.



PVP400 U/W UNIT ASSEM

Biospherical Instruments Inc.

4901 Morena Blvd., Suite 1003, San Diego, CA 92117



SEMBLY EXPLODED VIEW

Data Acquisition

The PVP-400 data acquisition subsystem consists of a Z8 microprocessor connected to a 12 bit plus sign integrating analog to digital converter. The input to the analog to digital converter is selected by an eight input multiplexer. The output of the multiplexer is fed to a programmable gain amplifier (PGA) which, under microprocessor control, automatically selects the gain with the highest resolution.

In a normal operation cycle, the microprocessor selects the first channel with the multiplexer, the gain is set to "1" and a conversion is done. If the measured voltage is less than conversion is completed. If the input voltage is less than another conversion is done. The data is stored in a buffer and the next channel is sampled in a like manner. **Conversion time** is a function of the input voltage and a low input voltage will require three conversions while a high voltage will require only one.

After the required number of channels have been sampled and the data are stored in the buffer, the buffer is transferred to the output buffer. Then, if handshaking is not required, the output buffer will be sent, preceded by the ASCII character "S". If hand shaking is required the buffer will not be sent until as ASCII "XON" character is received from the host computer. The "S" character is a Hex 53. The "XON" character is a Hex 11, or a "CONTROL Q".

DATA FORMAT

The data string begins with an ASCII character "S" followed by two bytes per channel. Assuming eight analog channels, then the data string will be 17 bytes long, and will take about 17 milliseconds to be transmitted at a baud rate of 9600 baud.

ANALOG FORMAT

Each analog channel is digitized two data bytes. The two bytes are coded as "two's complement" binary data. Two's complement data quantify all the data bits if the number is negative. The most significant bit is the sign bit; if '0', the number, is positive, if '1', the number, is negative. The next 12 bits are the data bits or the magnitude.

S	BBBB	BBBB	BBBB		
0	1111	1111	1111	=	4095
0	0000	0000	0100	=	4
0	0000	0000	0000	=	0
1	1111	1111	1111	=	-1
1	1111	1111	1011	=	-5
1	0000	0000	0000	=	-4095

The final three bits that are transmitted are the gain bits. Bit 0 ON indicates a gain of 1. Bit 1 ON indicates a gain of 16. Bit 2 ON indicates a gain of 256. Only one gain bit should be on at a time. All three gain bits ON indicate an over range condition.

```
S B B B  B B B B  B B B B  B G G G
----------------------------------
/-----2s compliment data---/ g g g
                             a a a
                             i i i
                             n n n
                             2 1 1
                             5 6
                             6
```

Then the PVP-400 is calibrated to read + or - 10.000 Volts full scale, the Smallest Resolution Element (SRE) at a GAIN of ONE is 2.442 millivolts (0.002442 Volts). This is found by dividing the full scale (10.0) Volts by the maximum reading (4095). Examples of calculated readings are given below.

First Byte	Second Byte	Voltage	Formula
0000 0000	0000 0100	= 0 volts	= 0 * SRE / 256
0000 0000	0000 1100	= .00000954 Volts	= 1 * SRE / 256
0100 0000	0000 0001	= 5.0012 Volts	= 2048 * SRE / 1
1011 1111	1111 1001	= -5.0012 Volts	= -20248 * SRE / 1
0111 1111	1111 1001	= 10.0000 Volts	= 4095 * SRE / 1

IV MAINTENANCE

There are two adjustments inside the instrument. One is the offset adjustment (R9). With the analog inputs to the instruments grounded, the output reading should be within 10 microvolts of ground potential. The other adjustment (R15) controls the full scale reading. This can be set by connecting any known voltage to the analog input and adjusting R15 until the output reads the same as the voltage that is connected to the analog input. It is probably best to use a lower voltage (below 30 millivolts) to make this adjustment. This will force the programmable gain amplifier to the higher gain where it is more sensitive. There may be some interaction between the two adjustments, therefore the other adjustments should be checked after making an adjustment.

Problems with the PVP-400 can be broken down into two major categories: 1) the data read from the PVP-400 is incorrect. One or more channels report the wrong voltage or the digital channels do not sense the correct level or are not able to be programmed; and 2) the PVP-400 does not respond at all.

A. INTEGRATED CIRCUITS FAILURE

The first problem probably is caused by one of the input or output integrated circuits failing. This can occur if the input voltage limits on the analog channels are exceeded, even if the overload only lasts a microsecond. **Walking across a carpet on a dry day can generate a static charge on a person that can deliver over 10,000 volts! Such a discharge can easily destroy an integrated circuit.**

If the analog voltage is incorrectly reported, then the most likely component to replace is the analog input multiplexer, U11. If the digital input/output channels are incorrect or impossible to control, then the digital buffer (U12) may need to be replaced. If this does not correct the problem, then consult the factory for further instructions.

B. NO RESPONSE

If the PVP-400 does not respond and you are using it for the first time, the most likely causes are:

1 Improper baud rate (also causes "garbage" to be received)

2 Incorrect setting of the DCE/DTE jumpers that assign Pins 2 and 3 of the RS-232 connector.

3 Incorrect wiring of the cable to the host computer. Remember, most computers or modems may require the CTS or RTS control lines to be at a certain state before data transmission can successfully occur.

4 Incorrect AC input voltage setting.

5 Incorrect host computer software for reading the input data stream.

If you have ruled out the above causes, check the fuse. If the problem is not remedied, **consult the factory for further assistance.**

V Parts List

REVISION DATE: MARCH 18, 1988

PARTS LIST FOR uP & A-D CIRCUIT BOARD

ASSMB.	REF #	BSI #	#USED	DESCRIPTION	MANUFACTURERS NUMBER	
CATEGORY................................RESISTORS AND POTS						
A1	R1	31.46800	1	680 KOHM 5% METAL FILM 1/4 W	ANY	ANY
A1	R2	33.47090	1	10 KOHM SIP 9 RESISTOR ARRAY	9S10E13A1002GL002	MCO
A1	R3	32.20100	1	10 KOHM 20 TURN UPRIGHT	66WR10K	BEK
A1	R4	30.21500	1	15.0 KOHM 1% 100PPM TEMPCO PREC.	RN55D1502F	ANY
A1	R5	31.42400	1	240 KOHM 5% METAL FILM 1/4 W	RC07GF244J	ALB
A1	R6	30.21780	1	17.8 KOHM 1% 100PPM TEMPCO PREC.	RN55C1782F	COR
A1	R7	30.21210	1	12.1K OHM ,1% 100PPM	RN55D1211F	ANY
A1	R8	30.31000	1	100 KOHM 1% 100PPM TEMPCO PREC.	RN55D1003F	ALB
A1	R9	32.21000	1	100 KOHM 20 TURN UPRIGHT	66WR100K	BEK
A1	R10	31.33900	1	39 KOHM 5% METAL FILM 1/4 W	RC07GF393J	ALB
A1	R11	31.58201	1	8.2 MOHM 5% METAL FILM 1/4 W	5043EM8M200J	MEP
A1	R12	31.24700	1	4.7 KOHM 5% METAL FILM 1/4 W	5043EM4K700J	MEP
A1	R13	30.22400	1	24.0 KOHM .1% 50PPM TEMPCO PREC.	RN55C2402F	COR
A1	R14	30.11501	1	1.5 KOHM .1% 50PPM TEMPCO PREC.	RN55C1501B	ANY
A1	R15	30.01001	1	100 OHM .1% 50PPM TEMPCO PREC.	RN55C1000B	ANY
A1	R16	31.27500	1	7.5 KOHM 5% METAL FILM 1/4 W	ANY	ANY
CATEGORY................................CAPACITORS						
A1	C1	40.15330	1	3.3uF, 16V TANTALUM	551-3.3M25	MOU
A1	C2	40.00100		10pF, 50V DISC	21CB010	MOU
A1	C3	40.00100	2	10pF, 50V DISC	21CB010	MOU
A1	C4	40.35100	1	1uF POLYESTER	23MA510	MOU
A1	C5	40.34331	1	.33uF POLYPROPYLENE	23PP433	MOU
A1	C6	40.34151	1	.15uF POLYPROPYLENE	23PP415	MOU
A1	C8	40.00680	1	68pF, 50V DISC	21CB068	MOU
A1	C50	40.03100		.01uF, 50V DISC	21EE010	MOU

ASSmb.	REF #	BSI #	#USED	DESCRIPTION	MANUFACTURERS NUMBER		
A1	U1	10.74131	1	CMOS 3-8 DECODER	74HC138	ANY	
A1	U2	10.74371	ı	CMOS TRI-STATE OCTAL D FLIP-FLOP	74HC374	MOU	
A1	U3	10.49080	1	DUAL CMOS 30V DRIVER	MM74C908	NSC	

PARTS LIST FOR uP & A-D CB

A1	U4	10.27640	1	CMOS 64K EPROM	27C64	HIT	3
A1	U5	10.80010	1	CMOS Z8 MICROPROCESSOR	LU800V1	SHP	4
A1	U6	10.71090	1	12-BIT BINARY A-D CONVERTER	ICL7109CPL	INT	2
A1	L7	10.61080	1	CMOS 8 CHANNEL ANALOG MUX	IH6108CPE	INT	1
A1	U8	10.50530	1	QUAD CMOS ANALOG SWITCH	IH5053	INT	2
A1	U9	10.01030	1	LOW BIAS CURRENT OP AMP	OPA 103CM	B-B	4
CATEGORY...............................CONNECTORS							
A1	J1	80.30161	1	16 PIN RT. ANGLE SOCKET HEADER	102617-6	AMP	
A1	J2	80.30220	1	20 PIN VERTICAL SOCKET HEADER	102619-8	AMP	
A1	J3	80.30200	1	20 PIN VERTICAL SOCKET RECEPTACLE	103253-6	AMP	
A1	J4	80.30210	1	20 PIN DOUBLE SKT HDR W/ MTG EARS	87606-6	AMP	
CATEGORY...............................CIRCUIT BOARDS							
A1	CB1	70.03001	1	CMOS Z8 MICROPROCESSOR & A-D CB	70.03001	PRE	8
CATEGORY...............................MECHANICAL PARTS							
A1	MP1	90.03008	1	NF300 CHASSIS	90.03008	CMS	7
A1	MP2	88.03008	4	1/4 HEX FEMALE STANDOFF (L=1/2)	A-3906-440-4	GLO	
A1	MP3	88.04431	4	1/4 HEX M/F STANDOFF (L=1/4)	A-7300-440-4	GLO	
CATEGORY...............................FASTENERS							
A1	FS1	85.04004	28	FLAT WASHER S/S	#4	ANY	
A1	FS2	85.04412	14	SPLIT LOCK WASHER S/S	#4	ANY	
A1	FS3	85.04413	3	INTERNAL TOOTH LOCK WASHER S/S	#4	ANY	
A1	FS4	85.04410	2	FLAT HEAD SOCKET MACHINE SCREW	4-40 x 1 1/4	ANY	
A1	FS5	85.04432	7	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 5/16	ANY	
A1	FS6	85.04417	8	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 3/8	ANY	

CATEGORY...............................SOCKETS

ASSno.	REF #	BSI #	USED	DESCRIPTION	MANUFACTURERS NUMBER	
CATEGORY..................................CRYSTALS						
A1	Y1	12.61440	1	6.144 MHz CRYSTAL	ME332-1061	MOU

PARTS LIST FOR PVP-400 UPPER SENSOR BOARD

CATEGORY..................................RESISTORS AND POTS						
A2	R1	30.61000	1	100 MOHM 5% 100PPM TEMPCO PREC.	MK632-100M	CAD
A2	R2	30.11030	2	1.0 KOHM 1% 100PPM TEMPCO PREC.	5043ED1K000F	MEP
A2	R3	30.12150		2.15 KOHM 1% 100PPM TEMPCO PREC.	RN55D2151F	ANY
A2	R4	31.61001	1	10 MOHM 5% METAL FILM 1/4 W	5043EM10M00J	MEP
A2	R5	30.11000		1.0 KOHM 1% 100PPM TEMPCO PREC.	5043ED1K000F	MEP
A2	R6	30.12150	2	2.15 KOHM 1% 100PPM TEMPCO PREC.	RN55D2151F	ANY
CATEGORY..................................CAPACITORS						
A2	C1	40.33221	1	.022uF POLYPROPYLENE	23PP322	MOU
A2	C2	40.00500	1	50pF, 50V DISC	21CD050	MOU
A2	C3	40.15330	2	3.3uF, 16V TANTALUM	551-3.3M25	MOU
A2	C4	40.15330		3.3uF, 16V TANTALUM	551-3.3M25	MOU
A2	C5	40.02100	2	.001uF, 50V DISC	21EE001	MOU
A2	C6	40.02100		.001uF, 50V DISC	21EE001	MOU
CATEGORY..................................INTEGRATED CIRCUITS						
A2	U1	10.00110	2	LOW OFFSET OP AMP (METAL CAN)	LM11CH	NSC
A2	U2	10.00110		LOW OFFSET OP AMP (METAL CAN)	LM11CH	NSC
CATEGORY..................................CONNECTORS						
A2	J1	80.30230	2	20 PIN POLARIZED RIBBON RECEPTACLE	499501-4	AMP
A2	J2	80.30220	1	20 PIN VERTICAL SOCKET HEADER	102619-8	AMP
CATEGORY..................................CIRCUIT BOARDS						
A2	CB1	70.01002		PREAMP BOARD FOR QSL-100	70.01002	MRY
A2	CB2	70.01002	2	PREAMP BOARD FOR QSL-100	70.01002	MRY

ASSno.	REF #	BSI #	20USED	DESCRIPTION	MANUFACTURERS NUMBER	
A3	R2	30.21000		10 KOHM 1% 100PPM TEMPCO PREC.	RN55D1002F	COR
A3	R3	31.11000		100 OHM 5% METAL FILM 1/4 W	RC07GF101J	ALB
A3	R4	31.11000	2	100 OHM 5% METAL FILM 1/4 W	RC07GF101J	ALB
A3	R5	31.42400	2	240 KOHM 5% METAL FILM 1/4 W	RC07GF244J	ALB
A3	R6	31.42400		240 KOHM 5% METAL FILM 1/4 W	RC07GF244J	ALB
CATEGORY.................................CAPACITORS						
A4	C1	40.26101	1	10uF, 100V RADIAL ELECTROLYTIC	19FX010	MOU
A3	C2	40.15330	3	3.3uF, 16V TANTALUM	551-3.3M25	MOU
A3	C3	40.15330		3.3uF, 16V TANTALUM	551-3.3M25	MOU
A3	C4	40.15330		3.3uF, 16V TANTALUM	551-3.3M25	MOU
A3	C5	40.04100		.1uF, 50V DISC	CY20C104M	CRL
A3	C6	40.04100	2	.1uF, 50V DISC	CY20C104M	CRL
CATEGORY.................................INTEGRATED CIRCUITS						
A3	U1	10.78120	1	+12V REGULATOR	7812CT	MOT
A3	U2	10.78050	1	+5V REGULATOR	7805CT	ANY
A3	U3	10.79050	1	-5V REGULATOR	7905CT	ANY
CATEGORY.................................CONNECTORS						
A3	J1	80.70010	1	.062 MOLEX 9 PIN RECEPTACLE	03-06-1092	MOL
A3	J2	80.30200	1	20 PIN VERTICAL SOCKET RECEPTACLE	103253-6	AMP
A3	J3	80.30130	8	.062 MOLEX CRIMP MALE CONTACT	02-06-6103	MOL
CATEGORY.............................. ...FASTENERS						
A3	FS1	85.04407	7	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 1/4	ANY
A3	FS2	85.04413	7	INTERNAL TOOTH LOCK WASHER S/S	#4	ANY
A3	FS3	85.04414	3	HEX NUT S/S	4-40	ANY
CATEGORY.............................. ...DIODES						
A3	CR1	15.10914		LOW LEVEL SIGNAL DIODE	1N914	ANY
A3	CR2	15.10914	4	LOW LEVEL SIGNAL DIODE	1N914	ANY
A3	CR3	15.10914		LOW LEVEL SIGNAL DIODE	1N914	ANY
A3	CR4	15.10914		LOW LEVEL SIGNAL DIODE	1N914	ANY
CATEGORY.................................POWER SUPPLIES						
A3	PS1	60.48030	1	5-12V IN, +/-15V DC-DC CONVERTER	CP-4803	EPC

PARTS LIST FOR PVP-400 TEMPERATURE PRESSURE & RADIANCE CIRCUIT BOARD

ASSMB.	REF #	BSI #	USED	DESCRIPTION	MANUFACTURERS NUMBER	
CATEGORY				RESISTORS AND POTS		
A4	R1	31.00000	4	VALUE TO BE DETERMINED	XXX	XXX
A4	R2	31.00000		VALUE TO BE DETERMINED	XXX	XXX
A4	R3	31.00000		VALUE TO BE DETERMINED	XXX	XXX
A4	R4	31.00000		VALUE TO BE DETERMINED	XXX	XXX
A4	R5	30.22400	1	24.0 KOHM .1% 50PPM TEMPCO PREC.	RN55C2402F	COR
A4	R6	30.14990	1	4.99 KOHM 1% 100PPM TEMPCO PREC.	RN55C4991B	COR
A4	R7	30.11000	1	1.0 KOHM 1% 100PPM TEMPCO PREC.	5043ED1K000F	MEP
CATEGORY				CAPACITORS		
A4	C2	40.05100	3	1uF, 50V DISC	CY30C105M	CRL
A4	C3	40.15330		3.3uF, 16V TANTALUM	551-3.3M25	MOU
A4	C4	40.15330	2	3.3uF, 16V TANTALUM	551-3.3M25	MOU
A4	C5	40.05100		1uF, 50V DISC	CY30C105M	CRL
A4	C6	40.05100		1uF, 50V DISC	CY30C105M	CRL
CATEGORY				INTEGRATED CIRCUITS		
A4	U2	10.03630	1	PRECISION INSTRUMENTATION AMP	LM363AH-500	NSC
A4	U3	10.00100	1	OP AMP & VOLTAGE REFERENCE	LM10CH	NSC
CATEGORY				CONNECTORS		
A4	J1	80.30160	1	16 PIN VERTICAL SOCKET RECEPTACLE	103253-4	AMP
A4	J2	80.50081	1	8 PIN TO-5 SOLDER SOCKET	50502-7	AMP
CATEGORY				CIRCUIT BOARDS		
A4	CB4	70.03004	1	NF300 TEMP, PRESSURE & RADIANCE CB	70.03004	NAT
CATEGORY				MECHANICAL PARTS		
A4	MP1	88.04431	3	1/4 HEX M/F STANDOFF (L=1/4)	A-7300-440-4	GLO
CATEGORY				FASTENERS		
A4	FS1	85.04407	1	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 1/4	ANY
A4	FS2	85.04413	1	INTERNAL TOOTH LOCK WASHER S/S	#4	ANY

ASSmb.	REF #	BSI #	22USED	DESCRIPTION	MANUFACTURERS NUMBER		
				PARTS LIST FOR PVP-400 LOWER SENSOR HEAD ASSEMBLY			
CATEGORY..........CONNECTORS							
A5	J1	80.20011	2	4 PIN BULKHEAD CONN (THREADED)	LSG-4-BCL	ENV	
A5	J2	80.70020	1	.062 MOLEX 9 PIN PLUG	03-06-2092	MOL	
A5	J3	80.30120	8	.062 MOLEX CRIMP FEMALE CONTACT	02-06-5103	MOL	
CATEGORY..........MECHANICAL PARTS							
A5	MP1	90.04001	1	Lower Sensor Head (NF)''	90.04001	CMS	5
A5	MP3	90.03003	1	NF300 PRESSURE XDUCER RET. PLATE	90.03003	CMS	1
A5	MP4	88.04431	4	1/4 HEX M/F STANDOFF (L=1/4)	A-7300-440-4	GLO	
A5	MP5	90.02006	1	2000 PLEXY CIRCUIT BD SPACER-SHORT	90.02006	PMM	
A5	MP15	88.03140	1	300 PSI MINIATURE PRESSURE XDUCER	PSI-9A	KEL	1
CATEGORY..........FASTENERS							
A5	FS3	85.04415	4	FLAT HEAD SOCKET MACHINE SCREW	4-40 x 1/2	ANY	
A5	FS4	85.06340	4	?			
CATEGORY..........O-RINGS							
A5	OR2	91.02360	1	NF300 HOUSING MAIN SEAL O-RING	2-236	AER	
				PARTS LIST FOR PVP-400 UPPER SENSOR HEAD ASSEMBLY			
CATEGORY..........MECHANICAL PARTS							
A6	MP1	90.04002	1	Upper Sensor Head	90.04002	CMS	6
A6	MP2	90.03007	1	NF300 CHASSIS RETAINER	CMS	CMS	
A6	MP3	90.04003	2	Cosine Sensor Retaining Ring	90.04003	CMS	1
A6	MP4	88.04431	6	1/4 HEX M/F STANDOFF (L=1/4)	A-7300-440-4	GLO	
CATEGORY..........OPTICAL PARTS							

CATEGORY..................................O-RINGS

ASSno.	REF #	BSI #	23USED	DESCRIPTION	MANUFACTURERS NUMBER		
A6	OR1	91.00114	2	CAP SEAL O-RING FOR QCP-200	A-114	AER	
\6	OR2	91.00114		CAP SEAL O-RING FOR QCP-200	A-114	AER	
A6	OR3	91.02360	1	NF300 HOUSING MAIN SEAL O-RING	2-236	AER	

PARTS LIST FOR PVP-400 HOUSING

CATEGORY..................................MECHANICAL PARTS

A7	MP1	90.03005	1	NF300 M, IN HOUSING	90.03005	CMS	2

PARTS LIST FOR PVP-400 DECK BOX

CATEGORY..................................RESISTORS AND POTS

A9	R1	31.24700	2	4.7 KOHM 5% METAL FILM 1/4 W	5043EM4K700J	MEP
A9	R2	31.24700		4.7 KOHM 5% METAL FILM 1/4 W	5043EM4K700J	MEP
A9	R3	31.12400	1	240 OHM 5% METAL FILM 1/4 W	5043EM240R0J	MEP
A9	R4	31.21200	1	1.2 KOHM 5% METAL FILM 1/4 W	ANY	ANY
A9	R5	31.21000	1	1.0 KOHM 5% METAL FILM 1/4 W	5043EM1K000J	MEP

CATEGORY..................................CAPACITORS

A9	C1	40.15330	1	3.3uF, 16V TANTALUM	551-3.3M25	MOU
A9	C2	40.16100	1	10uF, 16V TANTALUM	551-10M16	MOU

CATEGORY.... ....INTEGRATED CIRCUITS

A9	U1	10.04260	1	OPTOISOLATOR	4N26	GEI
A9	U2	10.14881	1	LINE DRIVER	MC1488P	MIR

ASSMB. REF #		BSI # 24USED	DESCRIPTION	MANUFACTURERS NUMBER	
CATEGORY..................................SWITCHES					
A9	S1	72.25010 1	SPST POWER SWITCH	7101-P3-DZQ	C&K
CATEGORY..................................DISPLAY DEVICES AND INDICATORS					
A9	DS1	50.00020 2	CLEAR LENS RED LED	579-4224RT	MOU
A9	DS2	50.00020	CLFAR LENS RED LED	579-4224RT	MOU
CATEGORY..................................BATTERIES					
A9 ?	B1		60.00400		

PARTS LIST FOR PVP-400 DECK BOX

CATEGORY..................................DIODES					
A9	CR1	15.14001 1	1 AMP, 50V DIODE	1N4001	ANY
CATEGORY..................................PAPER ITEMS					
A9	P1	80.00410 1			

PARTS LIST FOR QSR-240 REFERENCE SENSOR

CATEGORY..................................RESISTORS AND POTS					
A2	R1	31.51301 1	1.3 MOHM 5% METAL FILM	5043EM1M300J	MEP
A2	R2	31.11000 1	100 OHM 5% METAL FILM 1/4 W	RC07GF101J	ALB
CATEGORY..................................CAPACITORS					
A2	C1	40.01220 1	220pF, 50 DISC	AKA5GAT-22	SPR

ASSY.	REF #	BSI #	USED	DESCRIPTION	MANUFACTURERS NUMBER		
CATEGORY................................CONNECTORS							
A1	J1	80.10600	1	4 CONTACT BLKHD CONN FOR QSR-240	PT02H-8-4P	BNX	
CATEGORY................................CIRCUIT BOARDS							
A2	CB1	70.02001	1	LIGHT BOARD FOR QSP-200,240	70.02001	MRY	
CATEGORY................................MECHANICAL PARTS							
A1	MP1	88.09997	2	1/8" LONG #4 ROUND NYLON SPACER	RSN-4/2	SPM	
A1	MP2	88.00240	4	RUBBER INSTRUMENT FEET WITH INSERT	517-1670-W	MOU	
A1	MP3	90.10080	1	QSP-200/240 PHOTOCELL HOLDER	90.1008	GS	
A1	MP6	90.24000	1	QSR-240 MAIN HOUSING	90.2400	DPC	1
A1	MP7	90.24020	1	QSR-240 COLLECTOR SHIELD	90.2402	DPC	1
A1	MP8	90.24010	1	QSR-240 HOUSING BASE PLATE	90.2401	DPC	
CATEGORY................................OPTICAL PARTS							
A1	O1	25.00000	1	TEFLON BALL (TESTED)	25.0000	BSI	
A1	O6	25.00050	1	QSP AND QSR SHORT LIGHT PIPE	25.0005	BSI	

PARTS LIST FOR QSR-240 REFERENCE SENSOR

CATEGORY................................FASTENERS						
A1	FS1	85.04417	2	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 3/8	ANY
A1	FS2	85.06321	8	FLAT HEAD PHILLIPS MACH SCREW S/S	6-32 x 3/8	ANY
A1	FS3	85.06007	4	PAN HEAD PHILLIPS MACH SCREW S/S	6-32 x 1/4	ANY
A1	FS5	85.04412	6	SPLIT LOCK WASHER S/S	#4	ANY
A1	FS7	85.04407	4	PAN HEAD PHILLIPS MACH SCREW S/S	4-40 x 1/4	ANY
CATEGORY................................PHOTODETECTORS						
A1		PD1		20.10870		
CATEGORY................................O-RINGS						

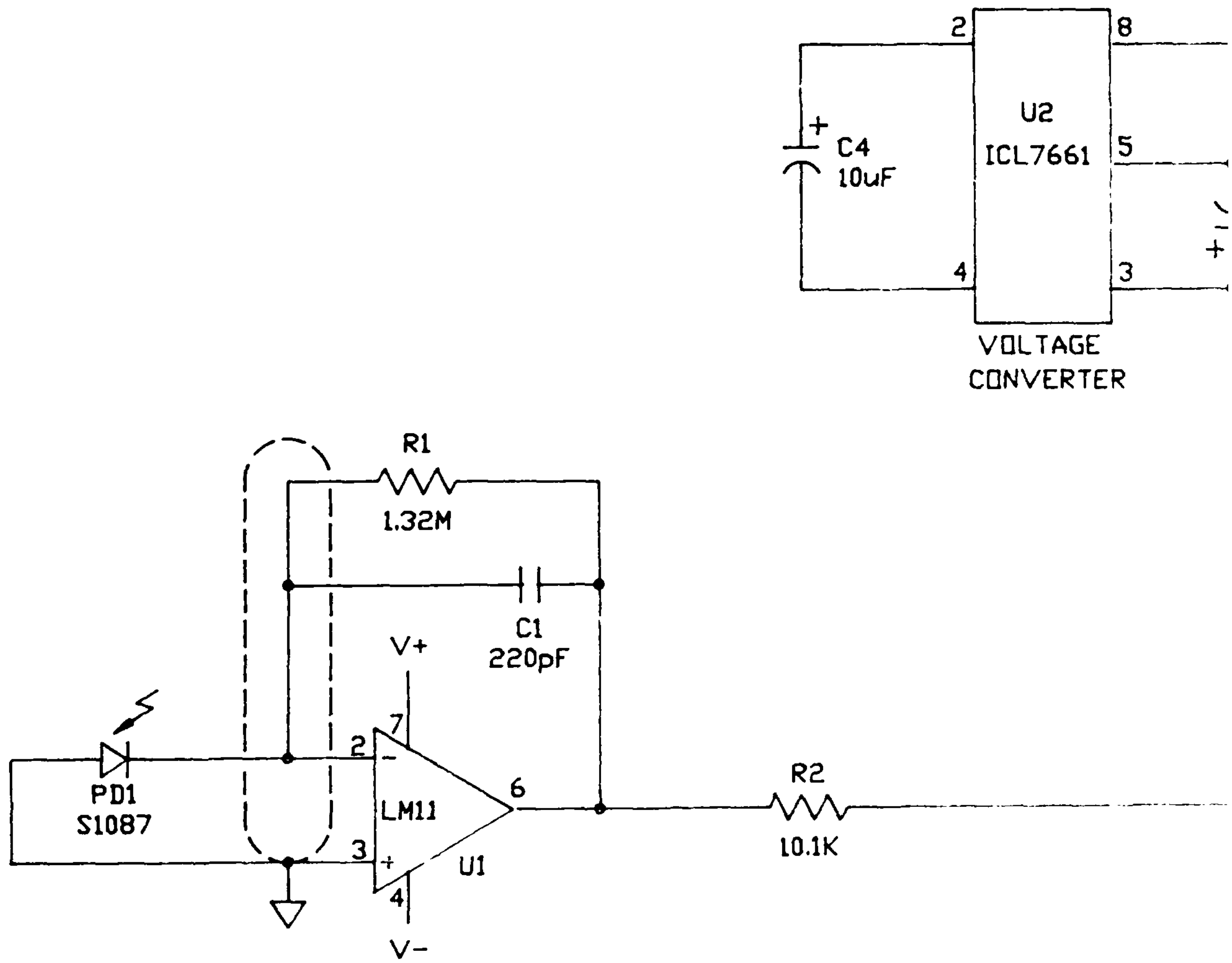
VI SCHEMATICS

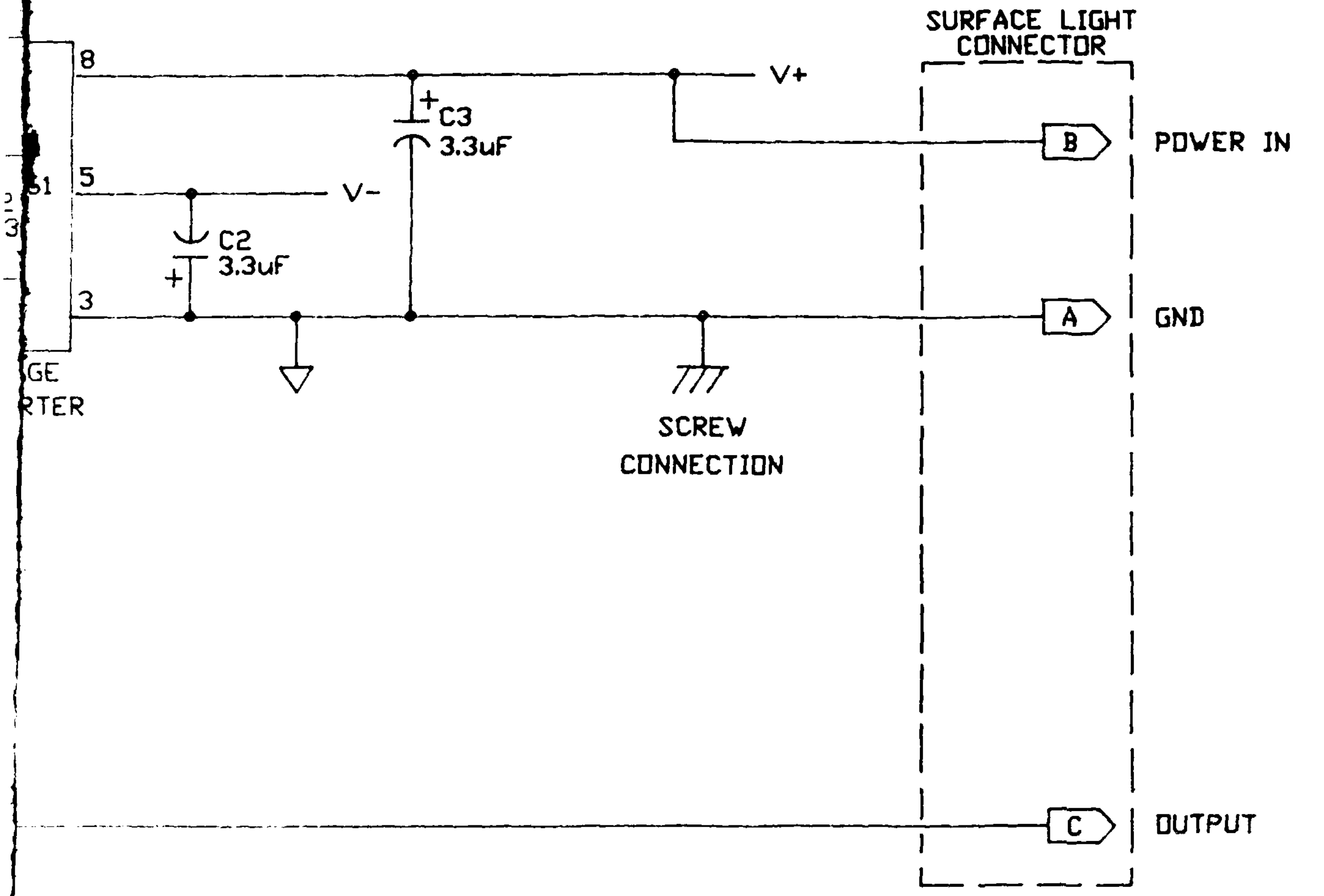
1 PVP-400 Surface Light Sensor
2 PVP-400 System Interconnections
3 PVP-400 Deckbox
4 PVP-400 Underwater Unit Connections
5 PVP-400 Z8 Board
6 PVP-400 Power Board
7 PVP-400 Upper Sensor Board
8 PVP-400 Lower Sensor Board

NOTES

1-ALL SYMBOLS PER ANSI Y13.2

2-ALL RESISTANCE VALUES IN OHMS





DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES:
.X ±.060
.XX ±.030
.XXX ±.010
ANGLES ±.5°

MATERIAL:

FINISH:

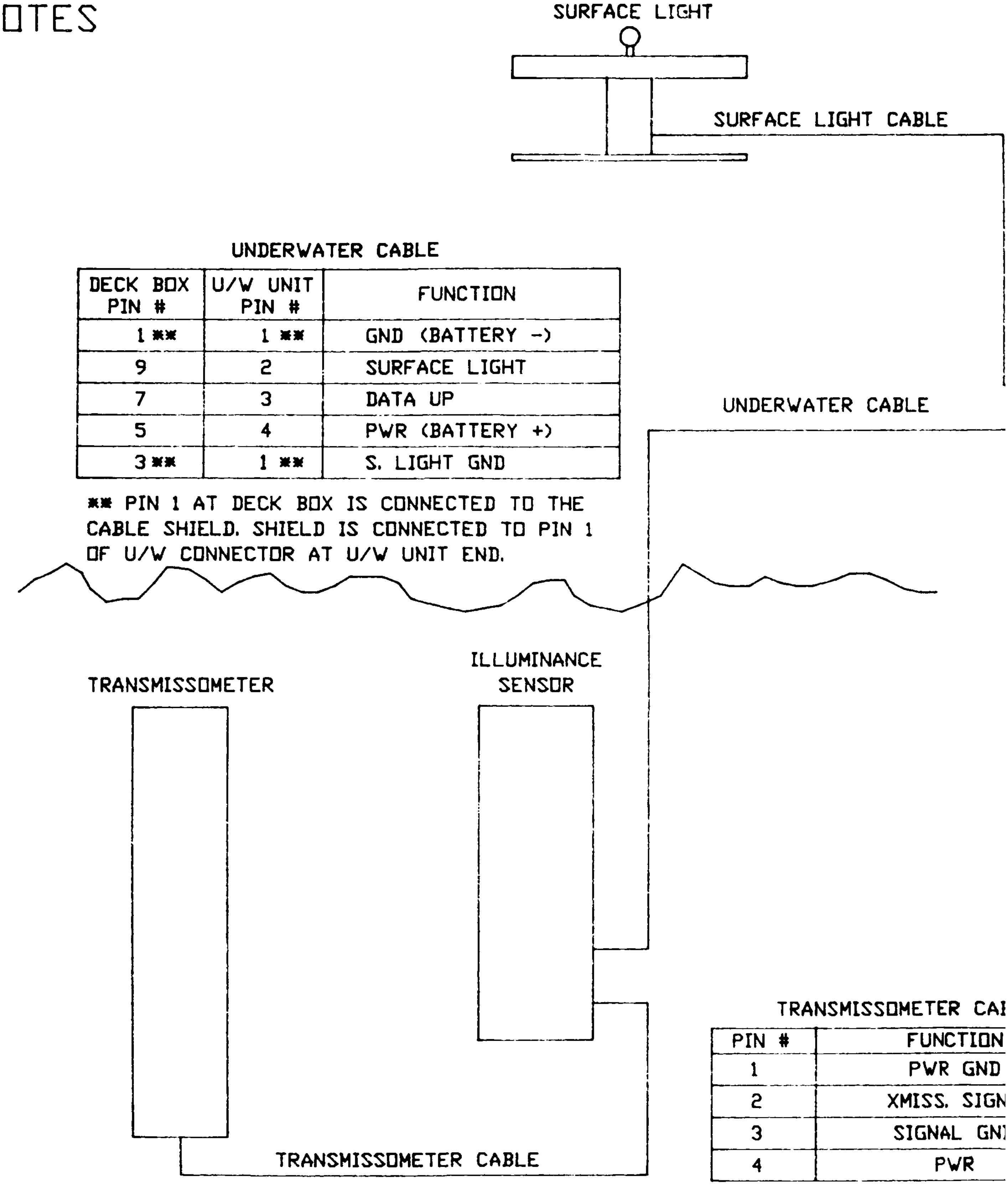
DO NOT SCALE DRAWING

Biospherical Instruments Inc.
4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLED "BIOSPHERE"

PVP400 S. LIGHT SENSOR SCHEMATIC

SIZE		DWG.NO.
C	G4SLTBD.DWG	03.04004
SCALE NONE	DATE 3/11/88 AR	SHEET 1 OF 1

NOTES



UNDERWATER CABLE

DECK BOX PIN #	U/W UNIT PIN #	FUNCTION
1 **	1 **	GND (BATTERY -)
9	2	SURFACE LIGHT
7	3	DATA UP
5	4	PWR (BATTERY +)
3 **	1 **	S. LIGHT GND

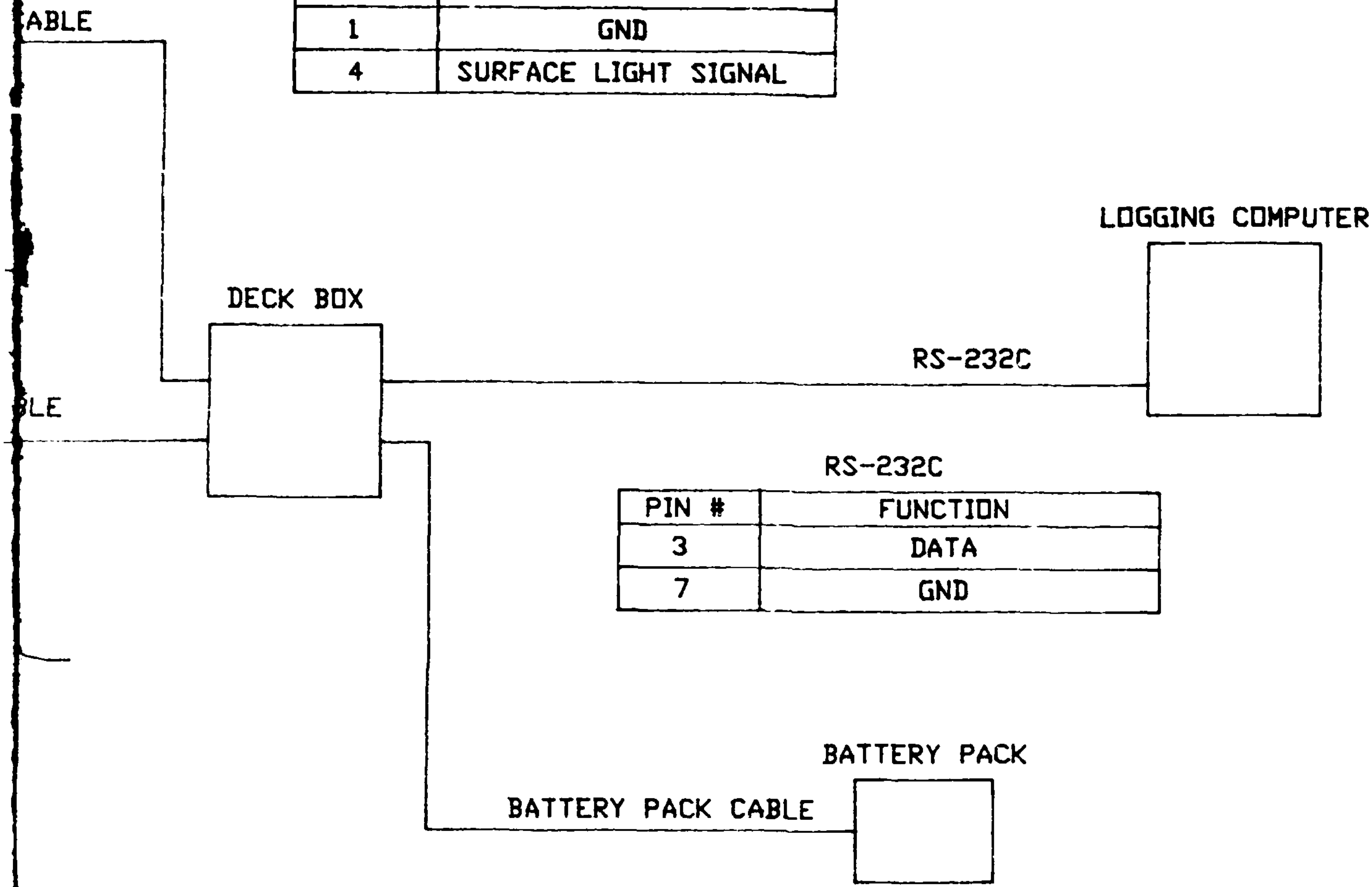
** PIN 1 AT DECK BOX IS CONNECTED TO THE CABLE SHIELD. SHIELD IS CONNECTED TO PIN 1 OF U/W CONNECTOR AT U/W UNIT END.

TRANSMISSOMETER CAI

PIN #	FUNCTION
1	PWR GND
2	XMISS. SIGN
3	SIGNAL GNI
4	PWR

SURFACE LIGHT CABLE

PIN #	FUNCTION
2	PWR
1	GND
4	SURFACE LIGHT SIGNAL



RS-232C

PIN #	FUNCTION
3	DATA
7	GND

BATTERY PACK CABLE

PIN #	FUNCTION
1	13V
2	N.C.
3	GND

METER CABLE

FUNCTION
PWR GND
MISS. SIGNAL
IGNAL GND
PWR

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES:
.X ±.060
.XX ±.030
.XXX ±.010
ANGLES ±.5°

MATERIAL:

FINISH:

DO NOT SCALE DRAWING

Biospherical Instruments Inc.

4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE "BIOSPHERE"

PVP400 SYSTEM INTERCONNECTIONS

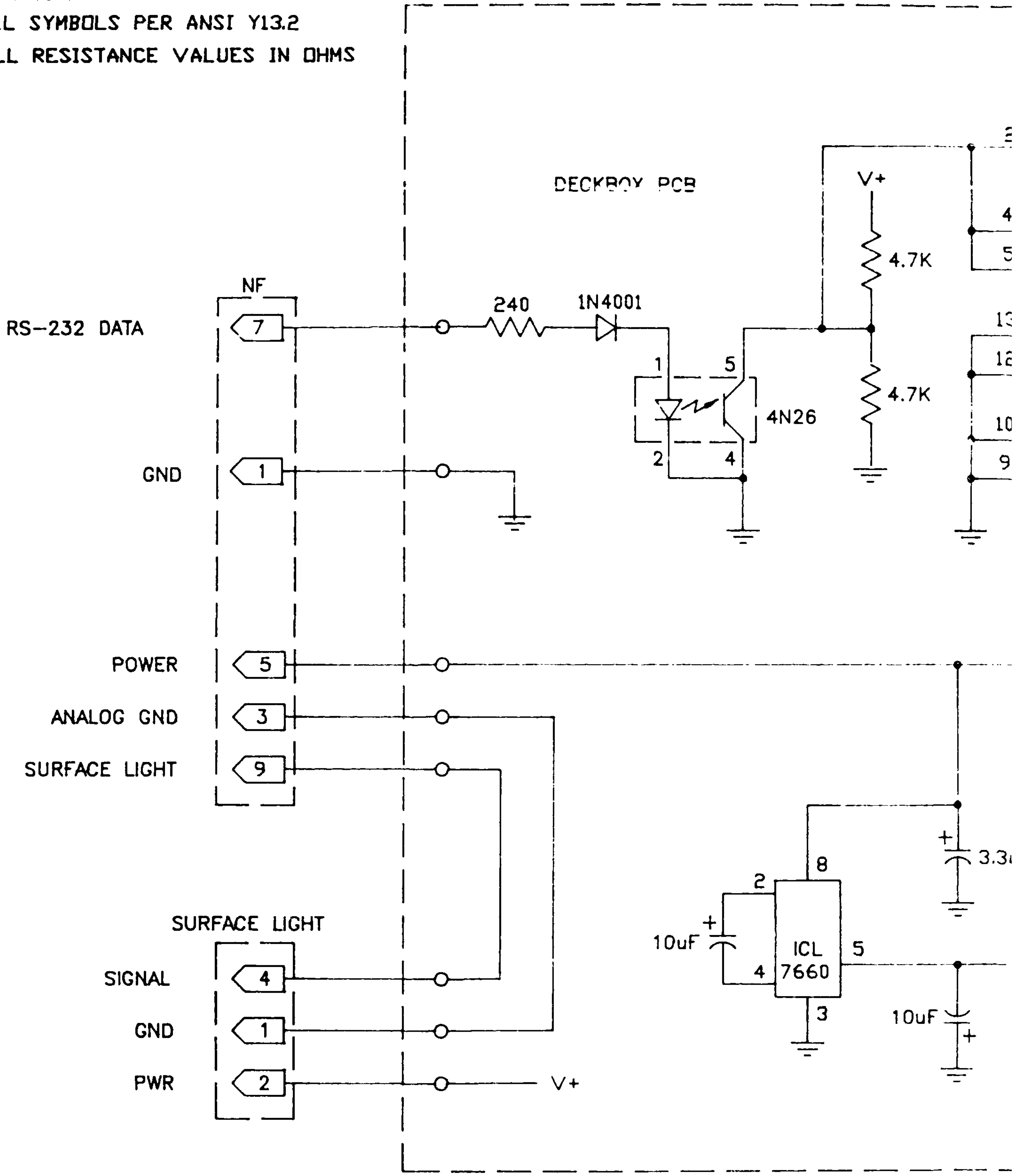
SIZE		DWG NO.
C	G4CONN.DWG	03.04001

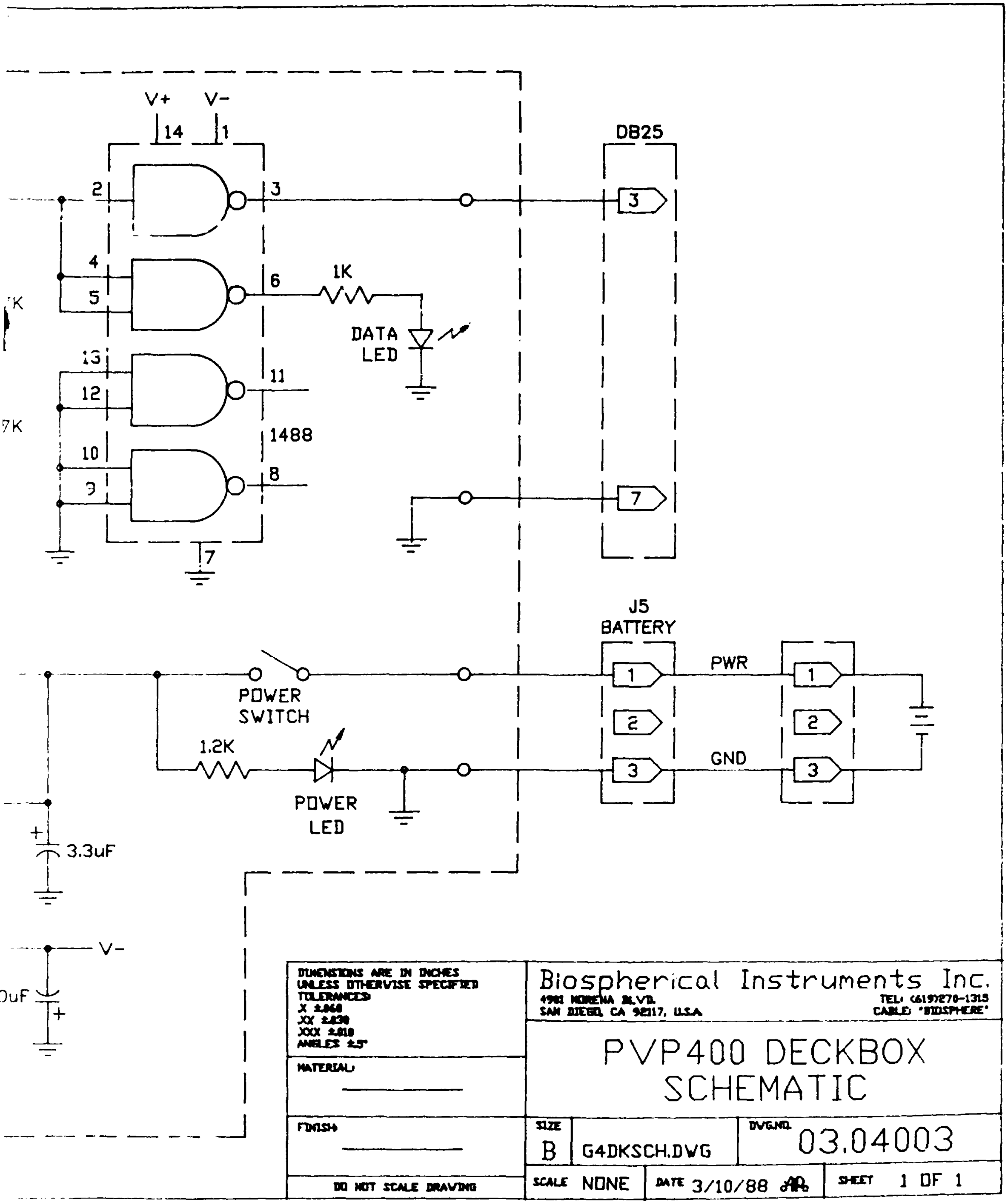
SCALE ---- DATE 3/8/88 SHEET 1 OF 1

NOTES

1-ALL SYMBOLS PER ANSI Y13.2

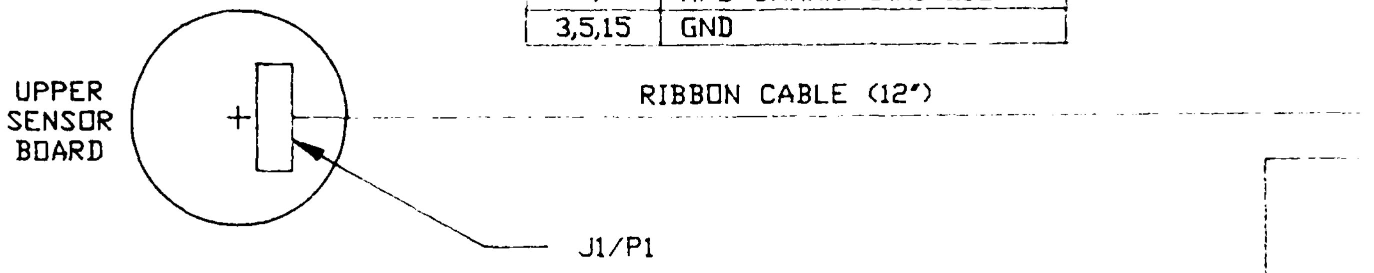
2-ALL RESISTANCE VALUES IN OHMS

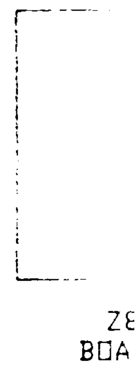



V+
V-
14
1
DB25
2
3
4
5
6
1K
DATA
LED
13
12
11
1488
10
9
8
7
J5
BATTERY
PWR
GND
1
2
3
POWER
SWITCH
1.2K
POWER
LED
3.3uF
V-
DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES:
X ±.060
XX ±.030
XXX ±.010
ANGLES ±.5°
MATERIAL:
FINISH:
DO NOT SCALE DRAWING
Biospherical Instruments Inc.
4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE: "BIOSPHERE"
PVP400 DECKBOX
SCHEMATIC
SIZE
B
G4DKSCH.DWG
DWG.NO.
03.04003
SCALE NONE
DATE 3/10/88
SHEET 1 OF 1

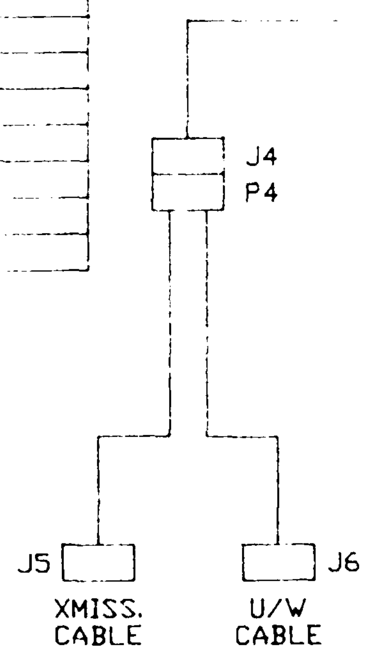
NOTES

PIN #	FUNCTION
7,8	+15V
9,10	+5V
11,12	GND
13,14	-15V
6	A/D CHANN. 2(LO-LIGHT)
16	A/D CHANN. 4(N.C.)
4	A/D CHANN. 5(HI-LIGHT)
3,5,15	GND





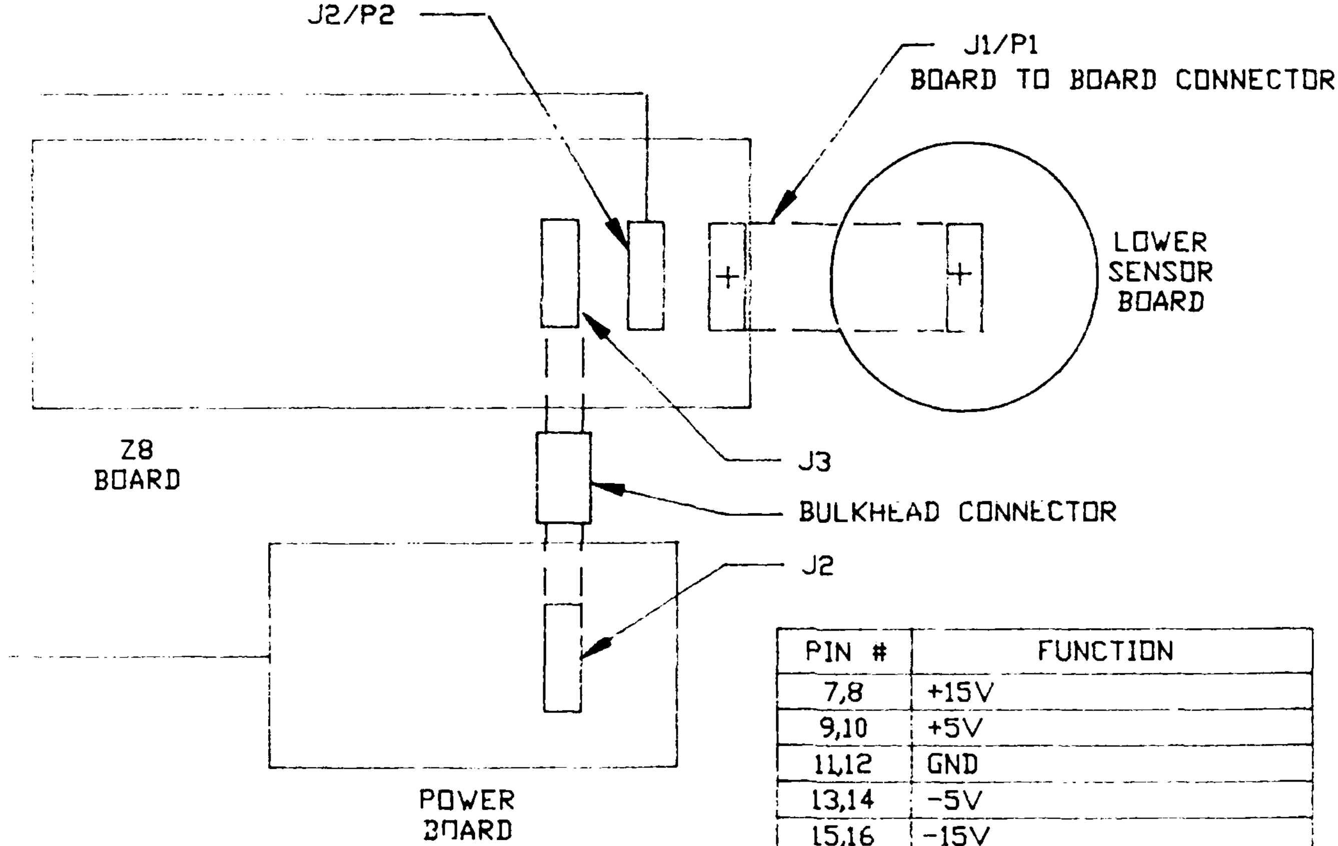
PIN #	FUNCTION
1,5	PWR GND
2	PWR
3	RS-232 OUT
4	SURFACE LIGHT
6	XMISS. IN
7	SIG GND
8	XMISS. PWR



PIN #	FUNCTION
1	PWR GND
2	XMISS. SIGNAL
3	SIG GND
4	PWR

PIN #	FUNCTION
1	GND (BATTERY-)
2	PWR (BATTERY+)
3	DATA UP (RS-232
4	SURFACE LIGHT

PIN #	FUNCTION
11,12	+15V
9,10	+5V
7,8	GND
5,6	-15V
4	A/D CHANN. 1(PRESSURE)
14	A/D CHANN. 4(N.C.)
16	A/D CHANN. 5(N.C.)



PIN #	FUNCTION
7,8	+15V
9,10	+5V
11,12	GND
13,14	-5V
15,16	-15V
4	A/D CHANN. 3(BATTERY)
2	A/D CHANN. 4(XMISS.)
6	A/D CHANN. 6(S. LIGHT)

UNCTION
TTERY-)
ATTERY+)
(RS-232 OUT)
LIGHT

DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES
X ±.060
XX ±.030
XXX ±.010
ANGLES ±.5°

MATERIAL

FINISH

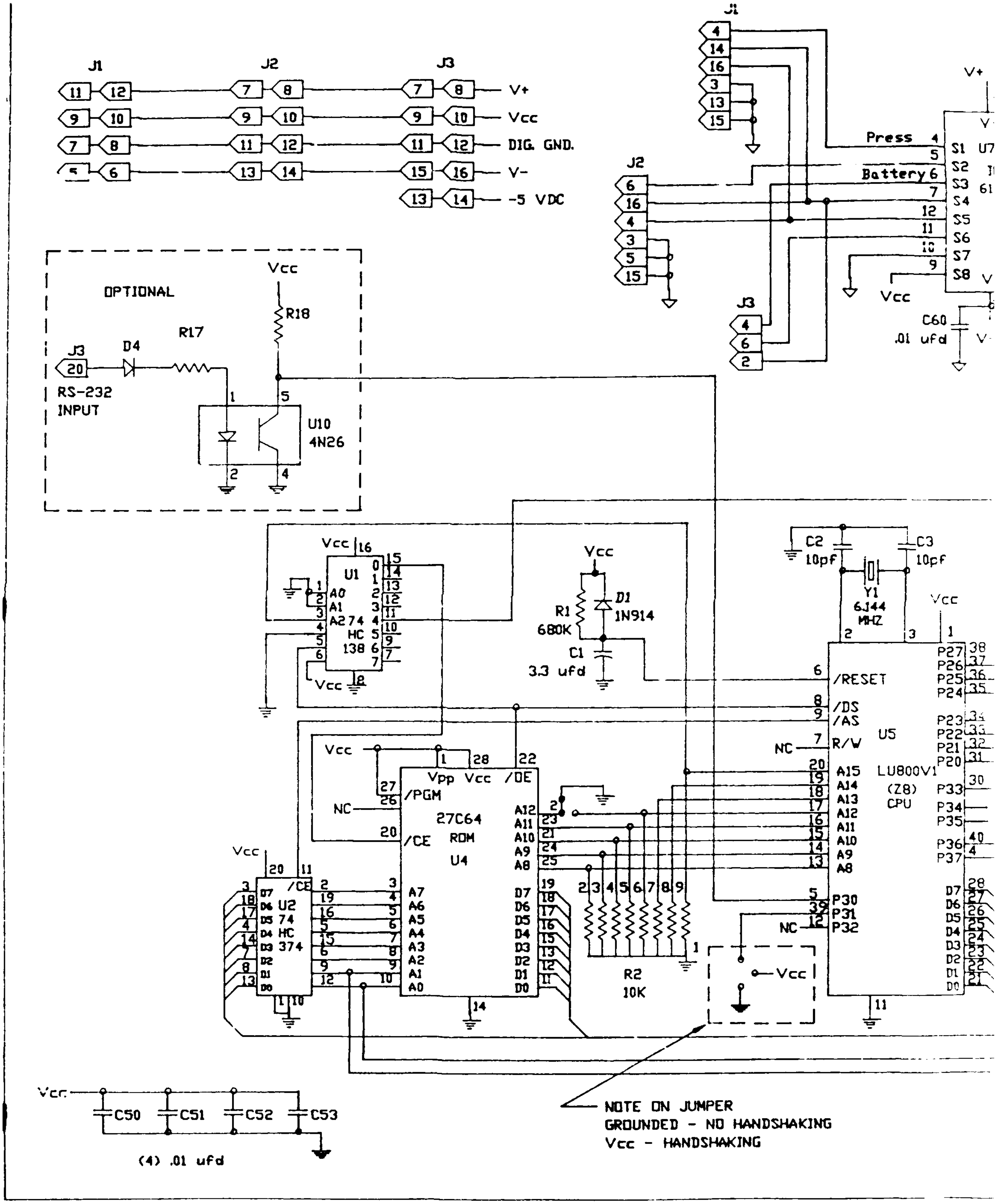
DO NOT SCALE DRAWING

Biospherical Instruments Inc.
4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE: "BIOSPHERE"

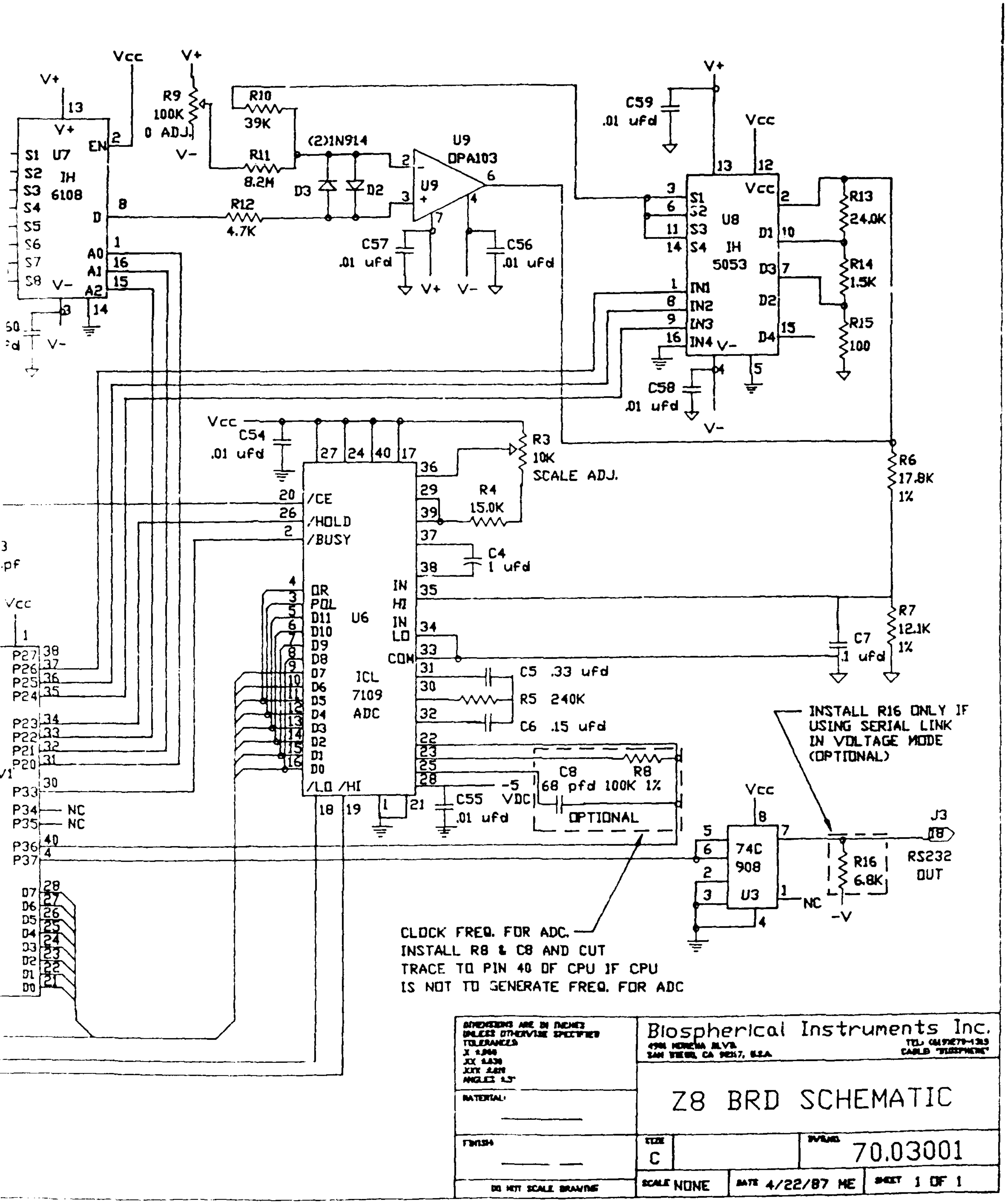
PVP400 U/W UNIT INTERCONNECTIONS

SIZE B | G4INSDIA.DWG | DWG.NO. 03.04002

SCALE NONE | DATE 3/9/88 AR | SHEET 1 OF 1



J1
J2
J3
V+
Vcc
DIG. GND.
V-
-5 VDC
OPTIONAL
R18
R17
D4
RS-232
INPUT
U10
4N26
Press
Battery
S1
S2
S3
S4
S5
S6
S7
S8
U7
C60
.01 ufd
U1
74
HC
138
R1
680K
D1
1N914
C1
3.3 ufd
C2
10pf
C3
10pf
Y1
6.144
MHZ
/RESET
/DS
/AS
R/W
NC
U5
LU800V1
(Z8)
CPU
/PGM
27C64
ROM
U4
/CE
/OE
Vpp
U2
74
HC
374
R2
10K
C50
C51
C52
C53
(4) .01 ufd
NOTE ON JUMPER
GROUNDED - NO HANDSHAKING
Vcc - HANDSHAKING

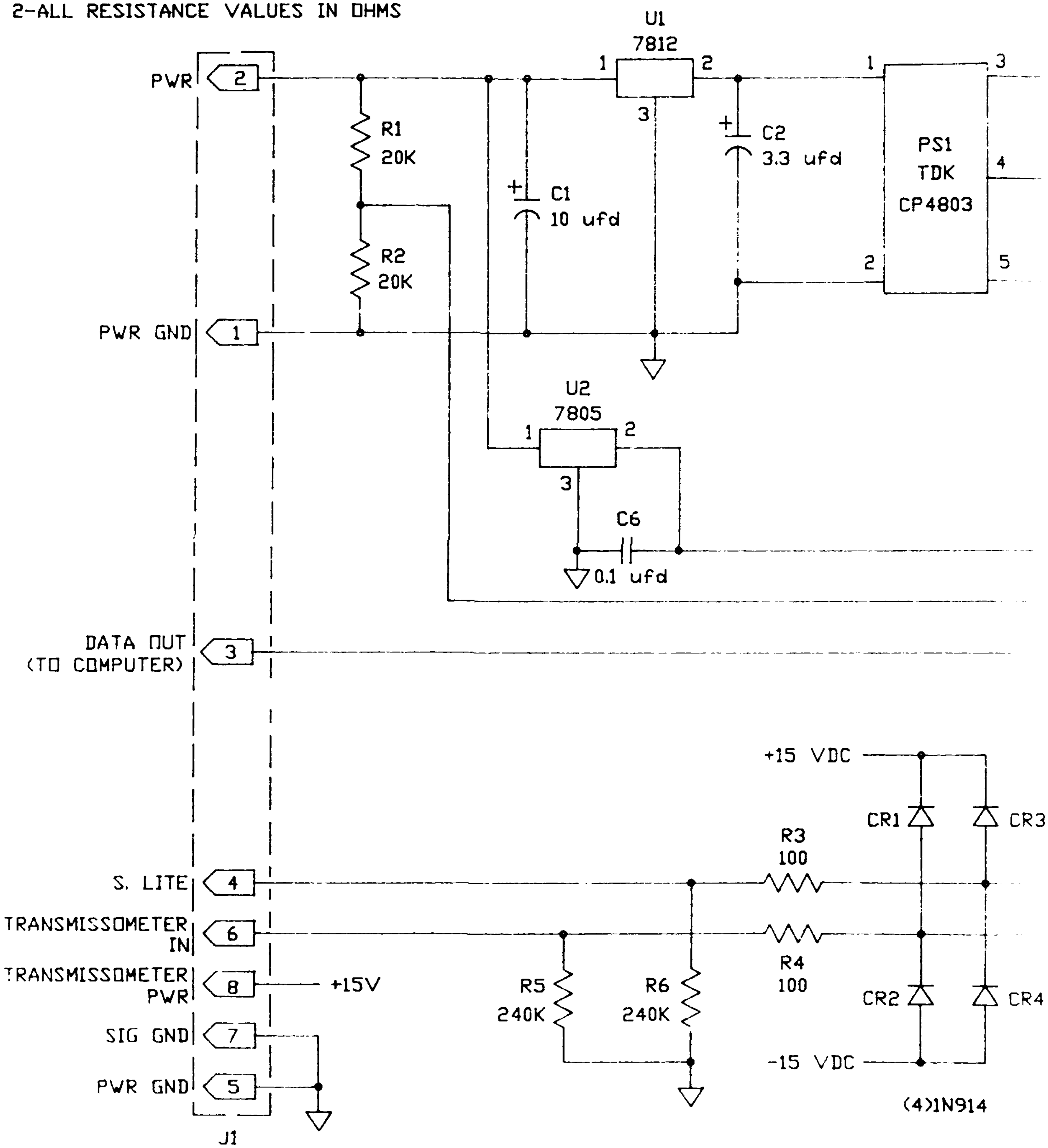


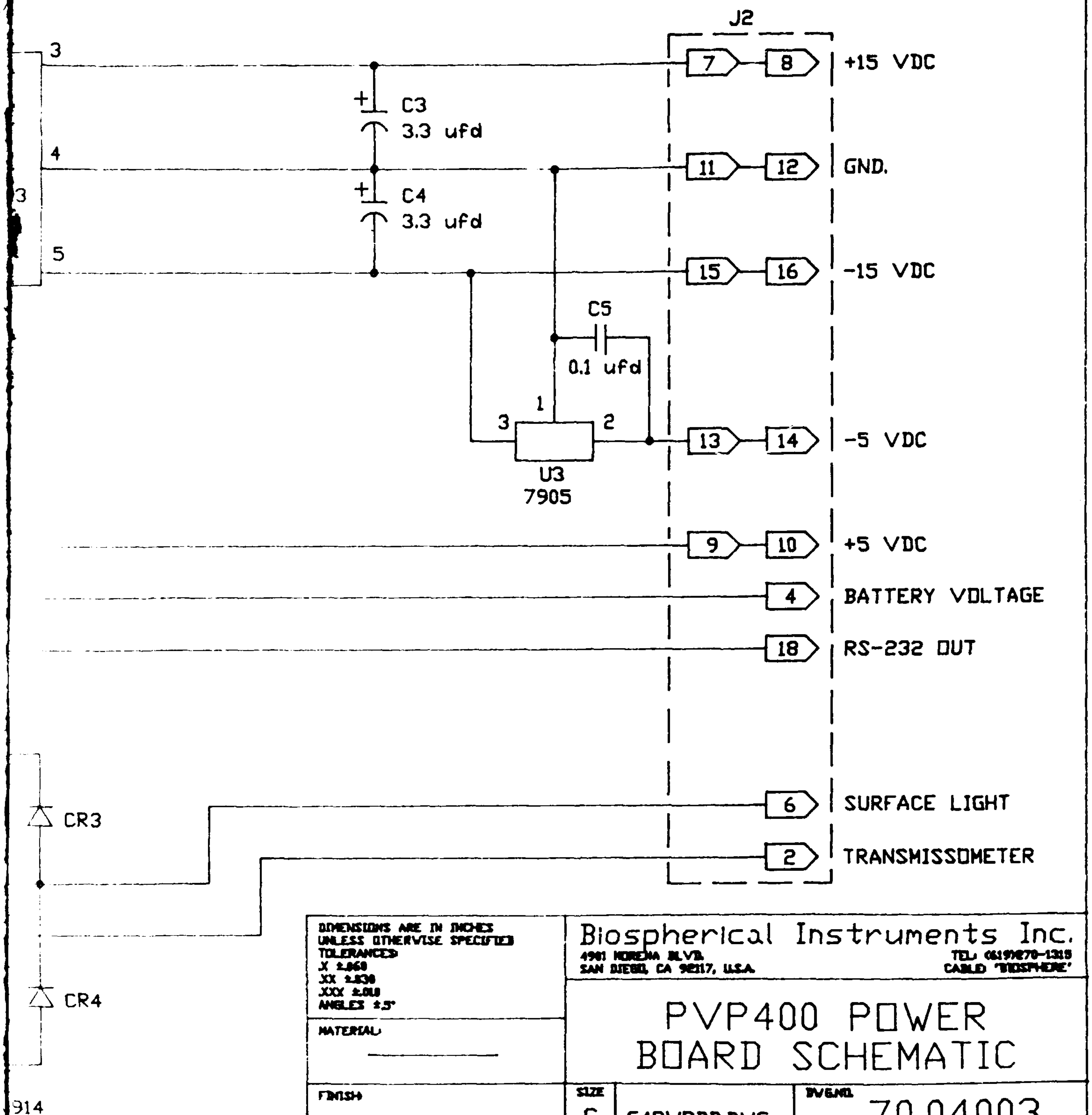
U7 IH 6108
R9 100K 0 ADJ.
R10 39K
R11 8.2M
R12 4.7K
(2)1N914
D3
D2
U9 OPA103
C57 .01 ufd
C56 .01 ufd
C59 .01 ufd
U8 IH 5053
R13 24.0K
R14 1.5K
R15 100
C58 .01 ufd
C54 .01 ufd
R3 10K SCALE ADJ.
R4 15.0K
C4 1 ufd
R6 17.8K 1%
R7 12.1K 1%
C7 .1 ufd
U6 ICL 7109 ADC
C5 .33 ufd
R5 240K
C6 .15 ufd
C8 68 pfd
R8 100K 1%
OPTIONAL
C55 .01 ufd
-5 VDC
INSTALL R16 ONLY IF USING SERIAL LINK IN VOLTAGE MODE (OPTIONAL)
74C 908 U3
R16 6.8K
J3
RS232 OUT
CLOCK FREQ. FOR ADC. INSTALL R8 & C8 AND CUT TRACE TO PIN 40 OF CPU IF CPU IS NOT TO GENERATE FREQ. FOR ADC
Biospherical Instruments Inc.
Z8 BRD SCHEMATIC
SIZE C
DWG NO. 70.03001
SCALE NONE
DATE 4/22/87 ME
SHEET 1 OF 1
DO NOT SCALE DRAWING

NOTES

1-ALL SYMBOLS PER ANSI Y13.2

2-ALL RESISTANCE VALUES IN OHMS





DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES:
.X ±.060
.XX ±.030
.XXX ±.010
ANGLES ±.5°

MATERIAL:

FINISH:

DO NOT SCALE DRAWING

Biospherical Instruments Inc.
4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE: "BIOSPHERE"

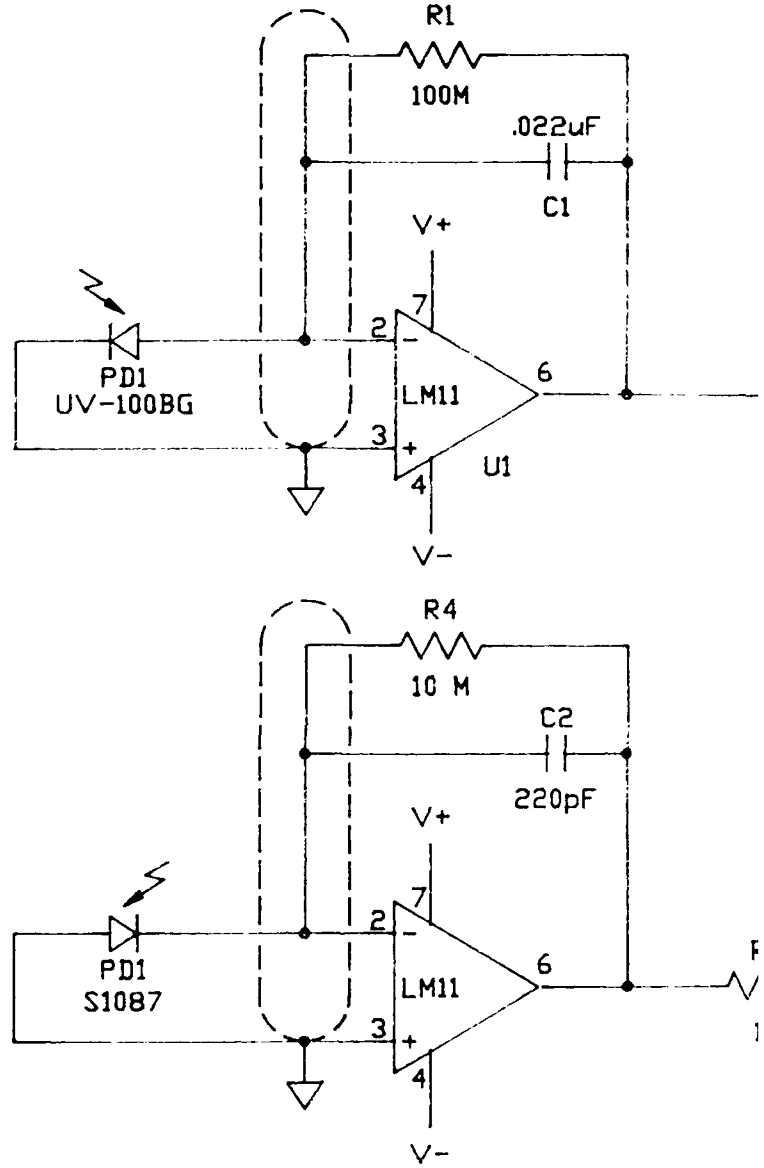
PVP400 POWER BOARD SCHEMATIC

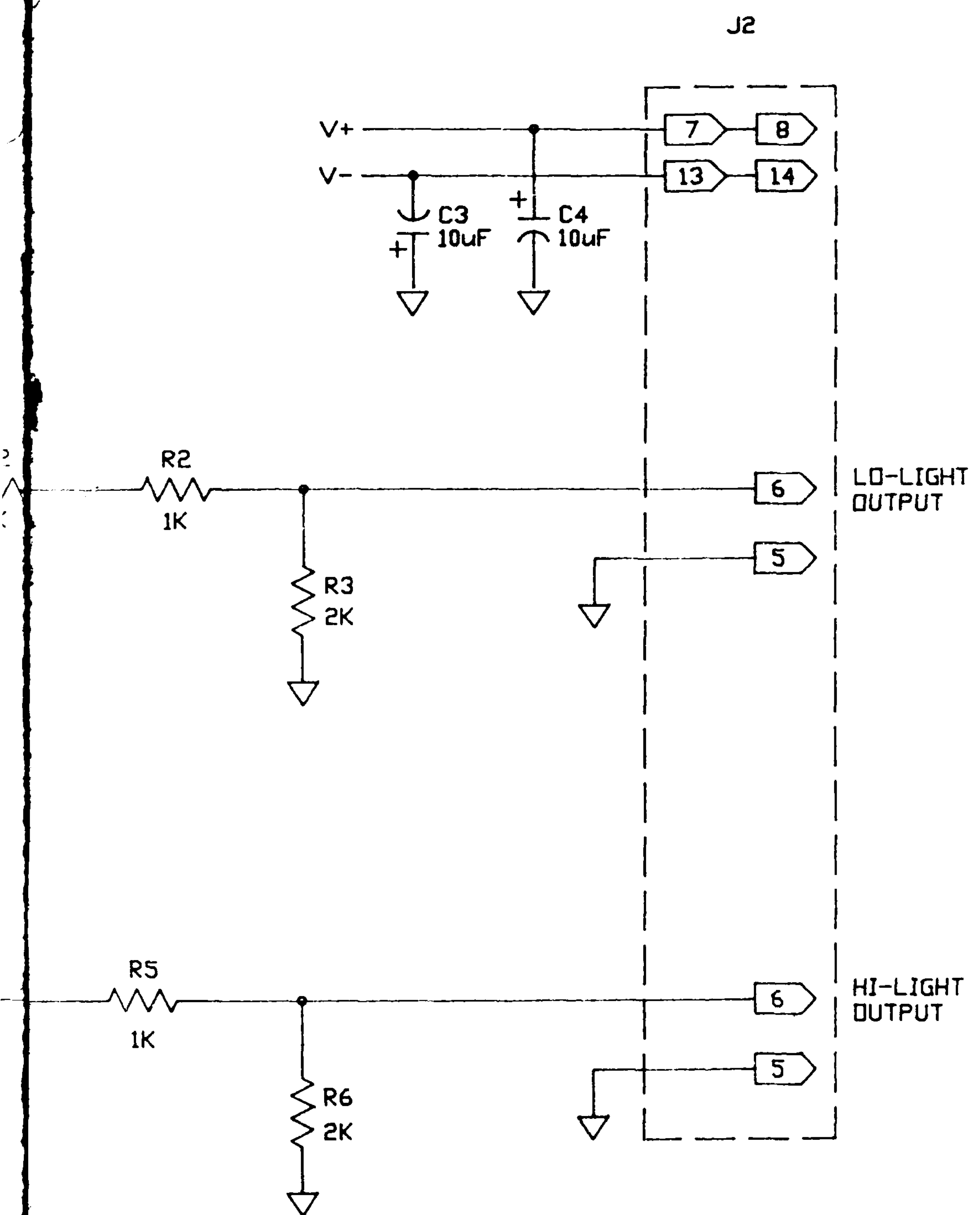
SIZE: C
G4PWRBD.DWG
DWG.NO. 70.04003
SCALE: NONE
DATE: 3/9/88 AD
SHEET 1 OF 1

NOTES

1-ALL SYMBOLS PER ANSI Y13.2

2-ALL RESISTANCE VALUES IN OHMS





DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES:
.X ±.060
.XX ±.030
.XXX ±.010
ANGLES ±.5°

MATERIAL: ____________

FINISH: ____________

DO NOT SCALE DRAWING

Biospherical Instruments Inc.

4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE: "BIOSPHERE"

PVP400 UPPER SENSOR BOARD SCHEMATIC

SIZE: C | G4USBSCH.DWG | DWG.NO. 70.04002

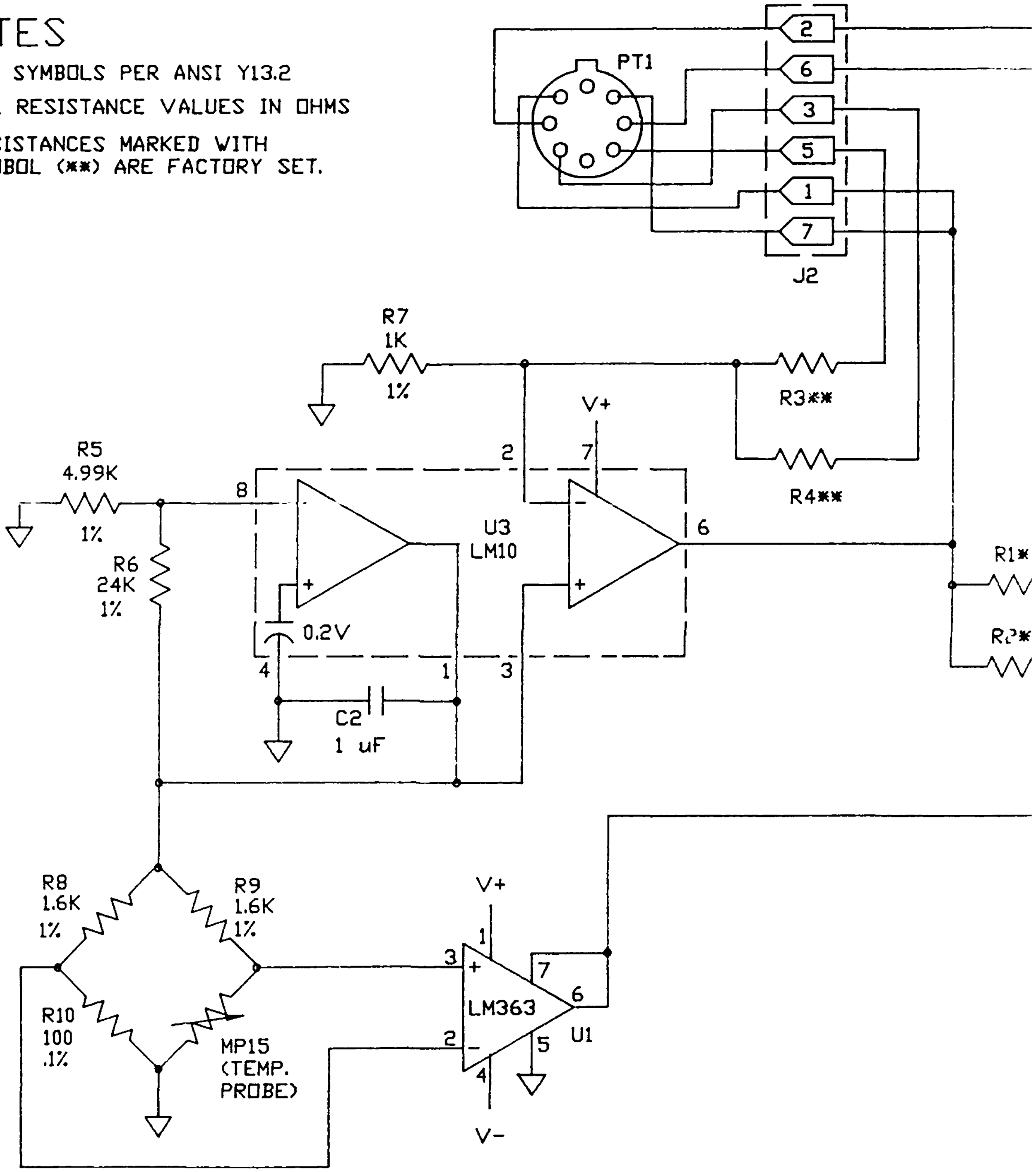
SCALE: NONE | DATE: 3/9/88 | SHEET 1 OF 1

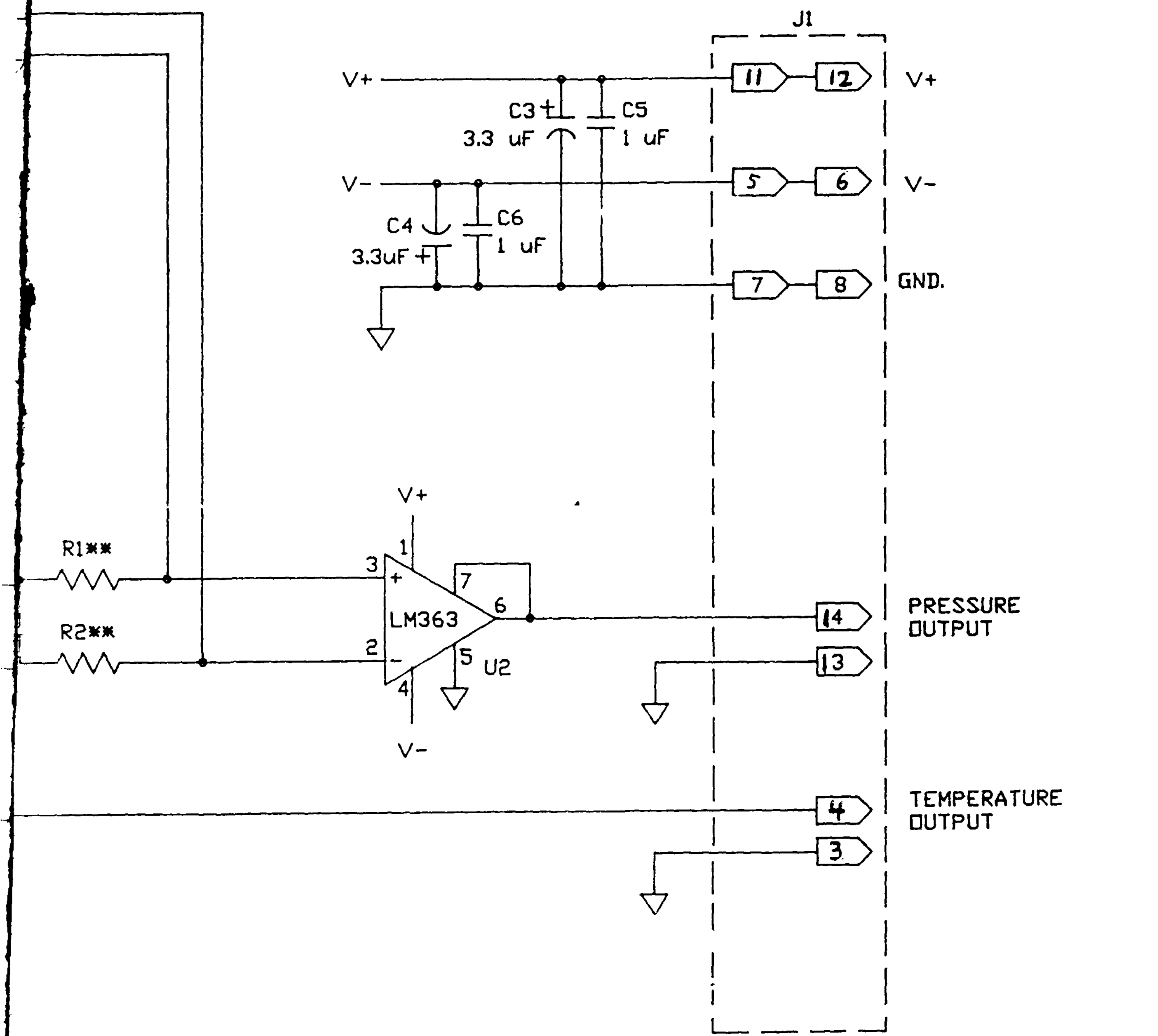
NOTES

1-ALL SYMBOLS PER ANSI Y13.2

2-ALL RESISTANCE VALUES IN OHMS

3-RESISTANCES MARKED WITH SYMBOL (**) ARE FACTORY SET.





DIMENSIONS ARE IN INCHES
UNLESS OTHERWISE SPECIFIED
TOLERANCES:
X ±.060
XX ±.030
XXX ±.010
ANGLES ±.5°

MATERIAL:

FINISH:

DO NOT SCALE DRAWING

Biospherical Instruments Inc.
4901 MORENA BLVD.
SAN DIEGO, CA 92117, U.S.A.
TEL: (619)270-1315
CABLE: "BIOSPHERE"

LOWER SENSOR BOARD SCHEMATIC

SIZE C

DWG.NO. 70.03004

SCALE NONE

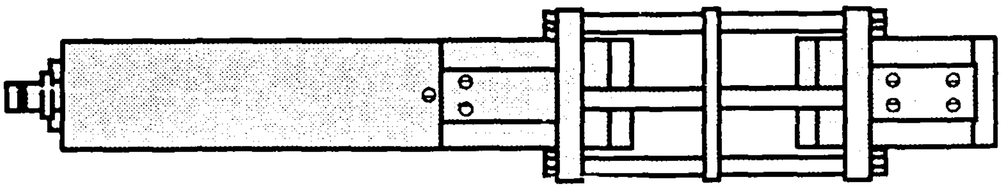
DATE 2/12/88

SHEET 1 OF 1

APPENDIX A
TRANSMISSOMETER MANUAL

SEA TECH INC. Telex 258519 CTEK
P.O. Box 779 • Corvallis, Oregon 97339 • (503) 757ˀ716

Transmissometer Manual



10 cm Transmissometer Side View

Serial Number 271

NOTE TO USERS:

This 10 cm beam transmissometer is a very delicate optical instrument. Please handle with care. Be sure windows are cleaned before each calibration and operation.

10 cm TRANSMISSOMETER

The transmissometer is designed to accurately measure beam transmission in a 10 centimeter water path. Transmission is measured using a modulated Light Emitting Diode (LED), and a synchronous detector. The instrument is not sensitive to ambient light, it is temperature compensated, and has excellent long term stability.

Optical design features a collimated LED transmitter with a beam divergence of less than three milliradians, and the optical receiver acceptance angle is less than eighteen milliradians in water. This well-collimated optical design minimizes errors caused by scattered light.

The transmissometer is constructed from plastic, (Celcon) which virtually eliminates any problems with corrosion in sea water.

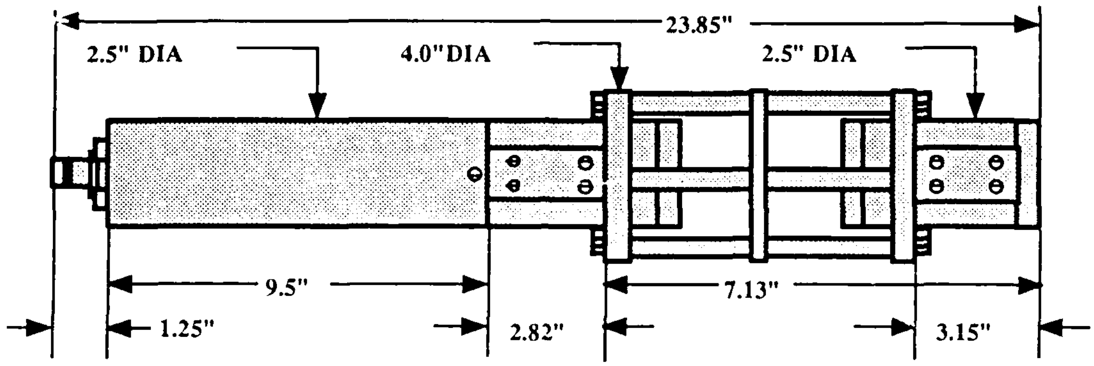
The instrument is portable, easily deployed and has low power requirements. It is supplied with mounting bracket and interconnecting cable, one half meter in length to facilitate mounting and checkout in the users system.

Several options and accessories are available to interface the transmissometer with recorders, current meters, CTD's, etc. Please contact Sea Tech for further information regarding these options and accessories.

LIMITED PRODUCT WARRANTY

For a period of one year from the date of shipment **SEA TECH, INC.** guarantees its products to be free from defects in materials and workmanship. In the event a product malfunctions during this period, the companys obligation is limited to repair of the defective item at our factory, or the defective item may be replaced at our option. Repairs or replacements under warranty will be at no cost to the customer. This warranty is void if, in our opinion, the instrument has been damaged by accident, mishandled, altered or repaired by the customer. The customer should call for Return Authorization before returning the instrument to the factory. Instruments should be returned prepaid and carefully packed in the original shipping container as the customer will be responsible for freight damage if the instrument is improperly packed. The customer will be charged a $100 minimum plus shipping costs if an instrument is returned for warranty repair and no defect is found by the factory. Incidental or consequential damages or costs incurred as a result of product malfunction are not the responsibility of **SEA TECH, INC.**

Outline Drawing, 10 cm Transmissometer, 2000 m



10 cm Transmissometer Specifications

Water Path Length		10 cm
Beam Diameter		15 mm
Transmitted Beam Collimation		< 3 milliradians
Receiver Acceptance Angle (in water)		< 18 milliradians
Light Source, Wavelength		LED, 670 nm
TRANSMISSION:	Range (in water)	0-100%, (0-5 VDC)
	Accuracy	+/- 0.5%
	Linearity	+/- 0.1%
	Temperature Stability	+/- 0.3%, (0-25°C)
POWER SUPPLY:	Voltage	9 to 15 VDC
	Current	≈ 10 ma
DIMENSIONS:	Length	60.6 cm
	Diameter	10.2 cm
WEIGHT:	In Air	2.7 kg
	In Water	1.5 kg
DEPTH CAPABILITY:		2,000 meters

Price: $4,500 **Delivery: 90 Days ARO** **Terms: Net 30 Days**

Latest Revision 11/15/87

10 cm TRANSMISSOMETER OPERATING INSTRUCTIONS

OPERATION & CALIBRATION:

First, connect a power source (9 to 15 VDC) to the instrument as shown on the connector wiring diagram, see figure 1. Observe polarity when connecting the power supply to the transmissometer, connect positive to pin 4 and negative to pin 1.

Use a voltmeter to measure the output voltage, pin 2 is the output and pin 3 is ground.

Block the light path to measure the zero output, it should be 0.00, +/- .01 VDC.

Clean the windows using kimwipes (or other nonabrasive material), with a solution of dishwashing liquid and water. When the windows are clean, the output voltage in air should be within +/- .02 VDC of the AIR CALIBRATION value listed below.

Perform the above procedure before each calibration and use of the instrument tc measure transmission of water. The wavelength of the source is 670 nm, and at this wavelength the maximum value for light transmission in clean water with a 10 cm pathlength is 96.4% (4.820 VDC). Pure water absorption is 3.6% for a 10 cm pathlength at 670 nm.

MOUNTING INSTRUCTIONS:

A mounting bracket is provided with the transmissometer to simplify mounting the instrument on your system, see figure 2.

PRECAUTIONS:

DO NOT OPEN THE INSTRUMENT--this voids the warranty. If the instrument does not function properly, please consult the factory.

DO NOT LEAVE THE INSTRUMENT ON WHEN NOT IN USE. The LED is quite stable, but it will decrease in intensity, like most light sources, if left on for a long period of time.

DATA REDUCTION:

Air calibration may change with time. The LED light output can decrease approximately 1% in 1000 hours of operation. If the air calibration is measured frequently and the following correction is applied, then this change can be compensated for and will not affect the accuracy of the data.

$$V=(A/B) \cdot (X-Z) \quad \text{and} \quad \%\ \text{Transmission} = 20 \cdot V$$

V=Corrected output voltage, (≤ 4.820 VDC since 96.4% is pure water).
A=Air calibration value listed below.
B=Air calibration (present value).
X=Data value (output voltage measured in water).
Z=Zero offset with light path blocked.

The AIR CALIBRATION for SN 271 was 4.752 VDC on 11-16 87

The ZERO OFFSET with the light path blocked is - 0.000 VDC

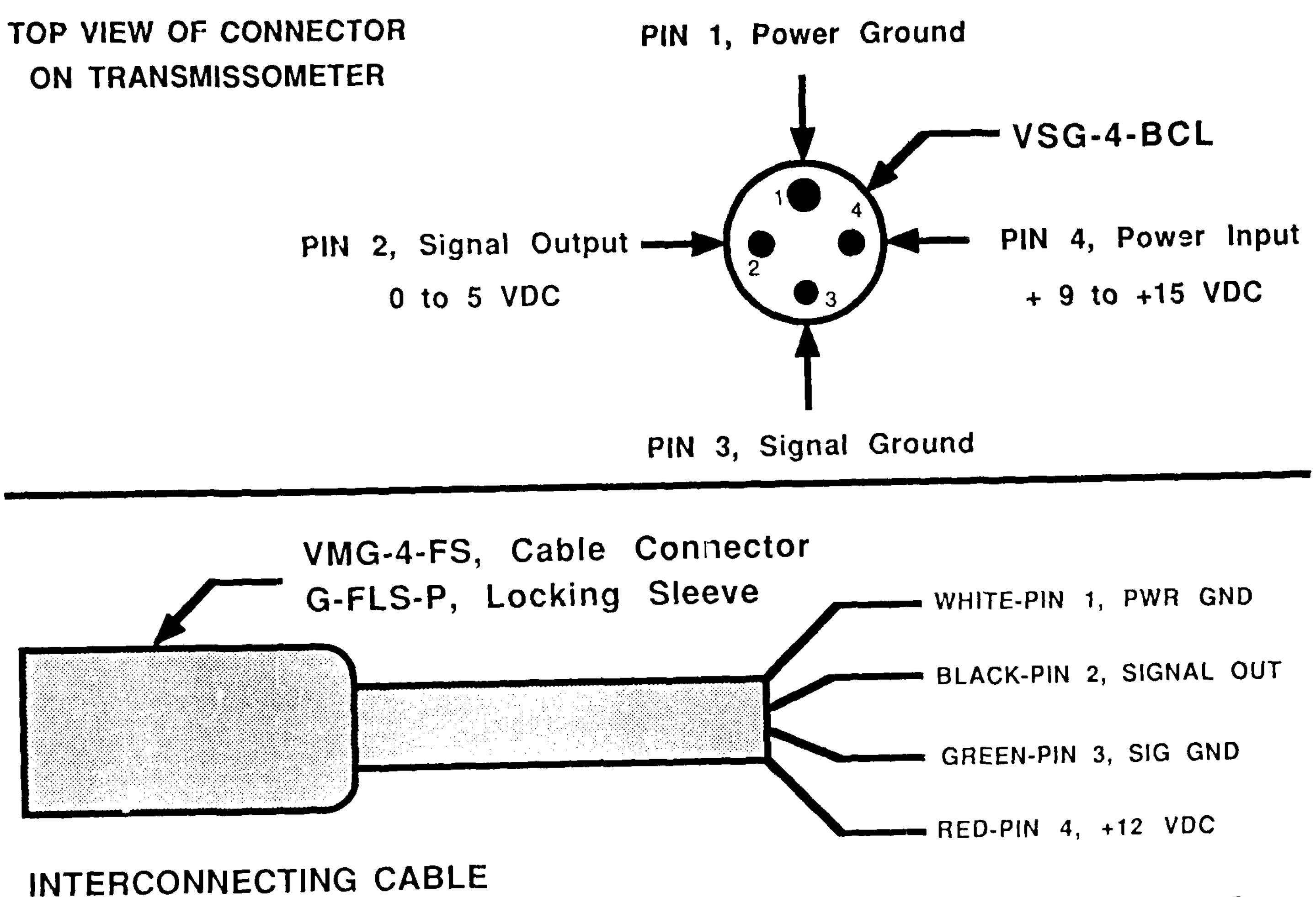
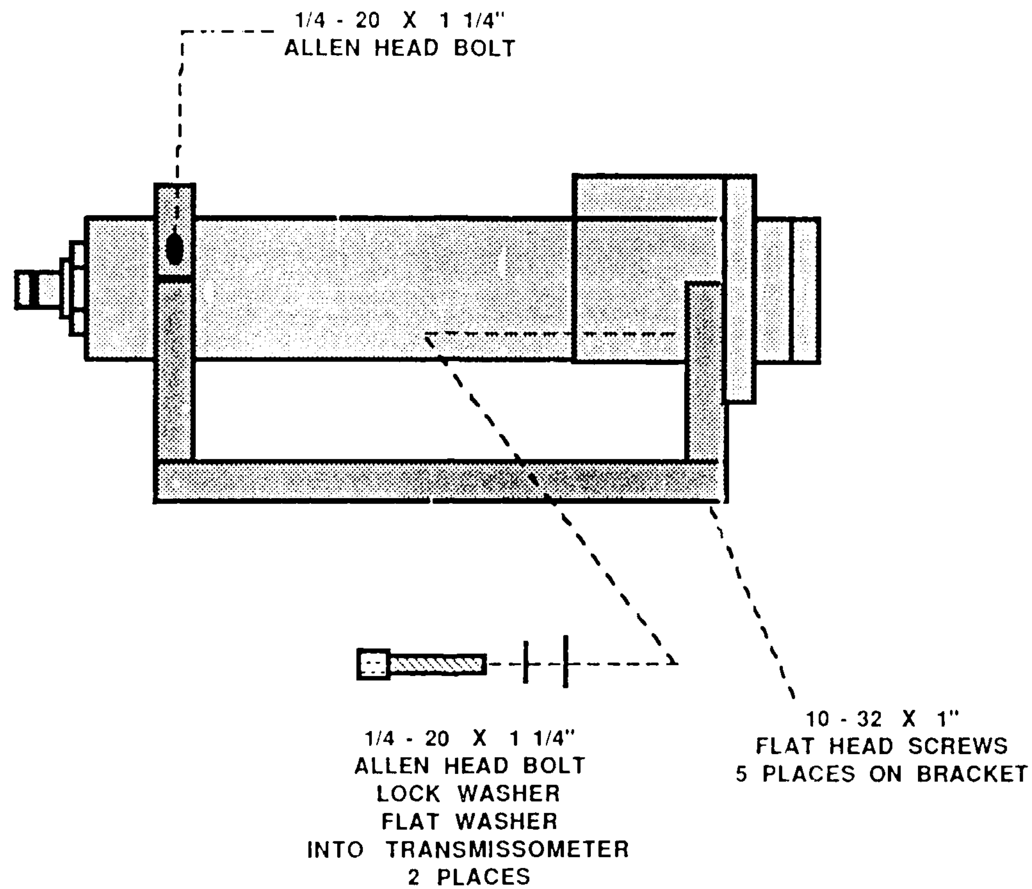
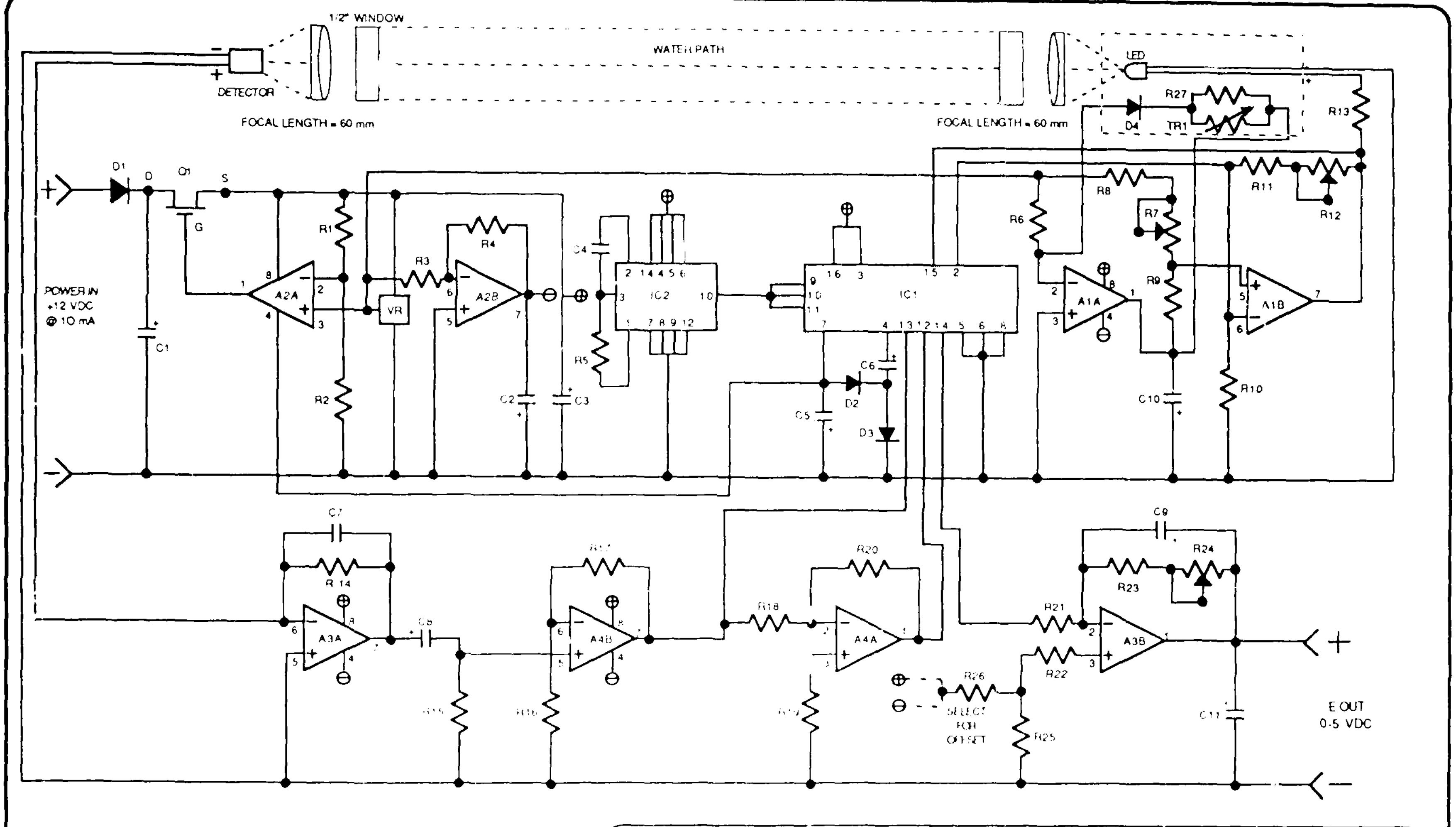


FIGURE 1, INTERCONNECTING CABLE WIRING



SEA TECH, INC. P.O. BOX 779 CORVALLIS, OR	FIGURE 2, TRANSMISSOMETER BRACKET	
	FILE: TRANSMISSOMETER MANUAL	
	MICHAEL McMENAMY	10/20/87



SEA TECH INC.
P.O. BOX 7'9
CORVALLIS, OR

FIGURE 3, TRANSMISSOMETER SCHEMATIC

FILE: TRANSMISSOMETER MANUAL

MICHAEL McMENAMY

11/18/87

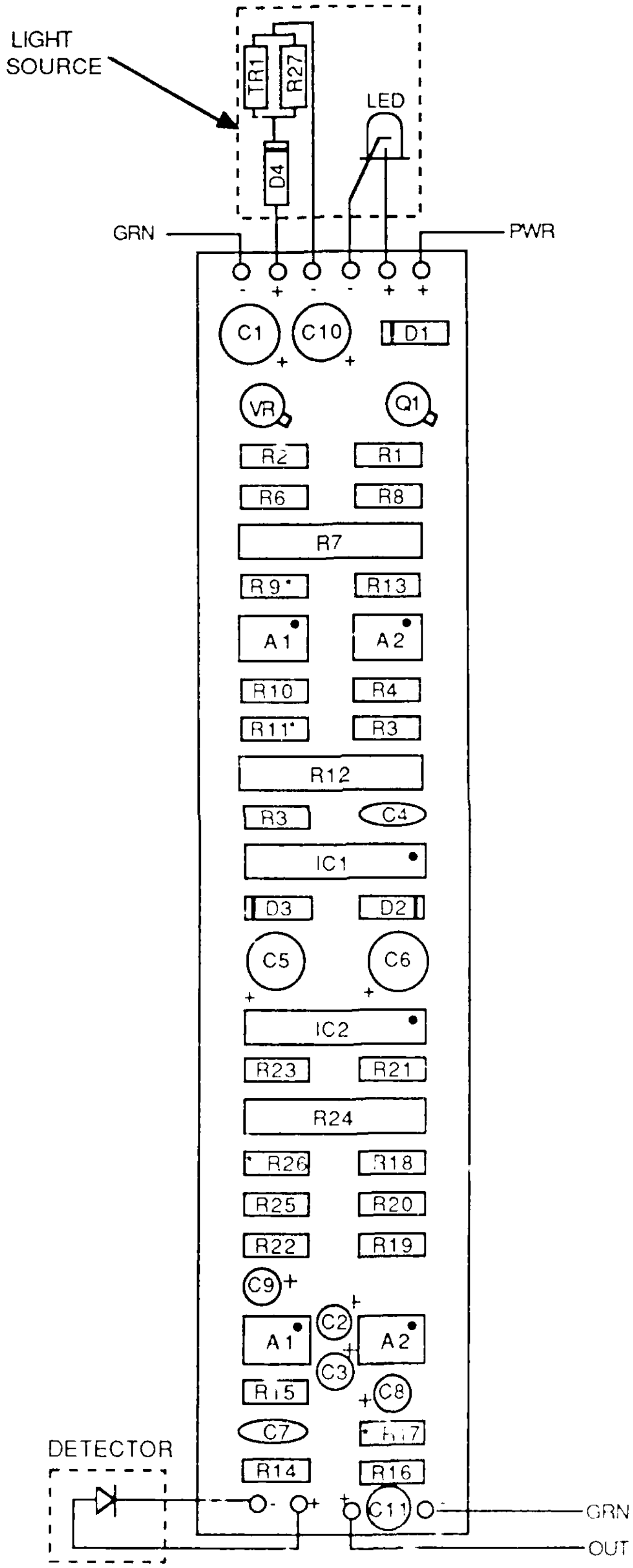


FIGURE 4, TRANSMISSOMETER CIRCUIT BOARD

McMENAMY

11/7/87

FILE: TRANSMISSOMETER MANUAL

* = SELECT AT TEST

SEA TECH INC.
P.O. BOX 779
CORVALLIS, OR

PAGE 9, TRANSMISSOMETER PARTS LIST

ITEM	VALUE	PART NUMBER	DESCRIPTION
R1	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R2	10K	RN55C1002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R3	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R4	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R5	499K	RN55C4993F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R6	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R7	1K POT	VRN 989-20-102	CERMET POTENTIOMETER, 20T
R8	7.5K	RN55C7501F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R9	SELECT	RN55C	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R10	1K	RN55C1001F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R11	SELECT	RN55C	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R12	1K POT	VRN 989-20-102	CERMET POTENTIOMETER, 20T
R13	470 OHM	RN55C4700F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R14	2 MEG	RN55C2004F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R15	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R16	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R17	SELECT	RN55C	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R18	10K	RN55C1002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R19	4.99K	RN55C4991F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R20	10K	RN55C1002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R21	20K	RN55C2002F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R22	17.4K	RN55C1742F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R23	82.5K	RN55C8252F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R24	20K POT	VRN 989-20-203	CERMET POTENTIOMETER, 20T
R25	100 OHM	RN55C1000F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R26	SELECT	RN55C	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
R27	2.74K	RN55C2741F	METAL FILM RESISTOR, 1/8 WATT, 1%, 30 PPM
C1	10uF	199D106X0035DA1	SOLID TANTALUM CAPACITOR, 35 VDC, 20%
C2	0.1uF	199D104X0035AA1	SOLID TANTALUM CAPACITOR, 50 VDC, 20%
C3	0.1uF	199D104X0035AA1	SOLID TANTALUM CAPACITOR, 50 VDC, 20%
C4	0.001uF	CN20102J	MONOLITHIC CAPACITOR, 100VDC, 10%
C5	15uF	199D156X0016CA1	SOLID TANTALUM CAPACITOR, 16 VDC, 20%
C6	15uF	199D156X0016CA1	SOLID TANTALUM CAPACITOR, 16 VDC, 20%
C7	5pF	DD050	MONOLITHIC CAPACITOR
C8	10uF	199D106X0035DA1	SOLID TANTALUM CAPACITOR, 35 VDC, 20%
C9	1uF	199D105X0035AA1	SOLID TANTALUM CAPACITOR, 35 VDC, 20%
C10	1uF	199D105X0035AA1	SOLID TANTALUM CAPACITOR, 35 VDC, 20%
C11	1uF	199D105X0035AA1	SOLID TANTALUM CAPACITOR, 35 VDC, 20%
D1	1N270	1N270	GENERAL PURPOSE GERMANIUM DIODE
D2	1N270	1N270	GENERAL PURPOSE GERMANIUM DIODE
D3	1N270	1N270	GENERAL PURPOSE GERMANIUM DIODE
D4	1N4454	1N4454	GENERAL PURPOSE SILICON DIODE
A1	LM358N	LM358N	DUAL OPERATIONAL AMPLIFIER
A2	LM358N	LM358N	DUAL OPERATIONAL AMPLIFIER
A3	TLO62CP	TLO62CP	DUAL BIFET OPERATIONAL AMPLIFIER
A4	TLO62CP	TLO62CP	DUAL BIFET OPERATIONAL AMPLIFIER
IC1	CD4047AE	CD4047AE	ASTABLE/MONOSTABLE MULTIVIBRATOR
IC2	CD4053BE	CD4053BE	MULTIPLEXER
Q1	J108	J108	FIELD EFFECT TRANSISTOR
VR	AD580MH	AD580MH	VOLTAGE REFERENCE
DE	UV100BQ	UV100BQ	DETECTOR
L1	FFE3100	FFE3100	LIGHT EMITTING DIODE
TR1	30K	YSI 44008	PRECISION THERMISTOR

INTRODUCTION

The Sea Tech 10 cm pathlength transmissometer has been designed to provide accurate in situ measurements of beam transmission and the concentration of suspended matter in relatively turbid waters.

The two basic processes that alter the underwater distribution of light are absorption and scattering. Absorption is a change of light energy into other forms of energy whereas scattering entails a change in direction of the light, but without loss of energy.

In a pure absorbing medium, the loss of light due to absorption in well-collimated beam of monochromatic light will be given by $I(z)= I(o)e^{-az}$, where "a" is the absorption coefficient with units of m^{-1}. Similarly, in a pure scattering medium, the light redirected from a well-collimated beam of monochromatic light will be given by $I(z) = I(o)e^{-bz}$, where "b" is the volume scattering coefficient with units of m^{-1}. Since attenuation is defined as the sum of absorption and scattering, we get a + b = c, where "c" is the beam attenuation coefficient.

The light lost from a well-collimated monochromatic beam of light in a scattering and absorbing medium is thus given by $I(z) = I(o)e^{-cz}$. This can be rewritten as $T(z)=I(z)/I(o) = e^{-cz}$, where T(z) is the percent light transmitted over a distance, "z". It should be noted that transmission is always over a given distance, whereas the beam attenuation coefficient, "c", is independent of distance. "c" is computed by $-\ln(T)/z$, where z is the pathlength of the instrument.

The simple exponential relationship holds only if the light is monochromatic. The Sea Tech transmissometer employs a light emitting diode (LED) light source with a wavelength of 670 nm, which is in the red part of the spectrum. This LED is nearly monochromatic.

A beam attenuation coefficient, "c", can be divided into three parts: 1) That due to water, c_w; 2) that due to suspended particulate matter, c_p; and 3) that due to dissolved materials (mostly humic acids or "yellow matter"), c_y. Hence, $c=c_w+c_p+c_y$. Each of these components has distinct spectral characteristics. Yellow matter absorbs strongly in the blue part of the spectrum. This absorption decreases exponentially with increasing wavelengths. The beam attenuation coefficient for particulate matter is much less wavelength dependent. It varies approximately as λ^{-1}. The attenuation spectrum of natural waters is a composite of the three components, depending on the relative concentrations. The yellow matter is a by-product of organic decay and can be present in large amounts in lakes, reservoirs, and near-shore waters. At 670 nm, the attenuation of yellow matter is negligible, however, so that the attenuation is due to particulate matter and sea water only.

INTERRELATION OF OPTICAL PARAMETERS AND PARTICULATE PROPERTIES

The light scattering characteristics of a single particle depend on it's shape, size, and internal index of refraction distribution. A typical collection consists of particles of many sizes, shapes and indices of refraction. These parameters, as well as the particle concentration, vary from location to location. It is thus to be expected that the relation between optical and particle parameters varies also.

Fortunately, the nature of suspended matter does not change much in a well-defined region, so that optical devices are useful for the determination of particle concentrations. In each region, however, the optical device must be separately calibrated against particle concentration. Off the Oregon coast, for example, Peterson (1977) found different slopes for the correlation of suspended mass and light transmission in the surface zone and near the bottom. It should also be noted that the correlation between particle concentration and beam attenuation is linear.

Linearity of the optical device as a function of particle concentration is highly desirable, and not too difficult to accomplish if reasonable precautions are taken as will be shown below.

A given type of particulate matter has a given beam attenuation coefficient $c_p{}^*$ per unit volume for a given wavelength. For N particles per unit volume the attenuation coefficient is $Nc_p{}^*$. The total attenuation coefficient must also include water, c_W and since the wavelength is in the red we can ignore yellow matter, c_y so :

$$c = c_W + Nc_p{}^*$$

The attenuation of a well-collimated beam of light is then:

$$I(z)/I(o) = e^{-cz} = e^{-(c_W + Nc_p{}^*)z}$$

or:

$$I(z)/I(o) = e^{-c_W z} \exp^{-Nc_p{}^* z}$$

$e^{-c_W z}$ is a constant for a given instrument at a given wavelength, so we set it equal to T_W. We then get:

$$I(z)/I(o) = T_W e^{-Nc_p{}^* z}$$

and taking the logarithm:

$$Ln[I(z)/I(o)] = Ln(T_W) - Nc_p{}^* z$$

Since $I(z)/I(o)$ is the transmission and $Ln(T_W)$ is a constant (set it K_1) and $c_p{}^*z$ is also a constant (set it K_2), we then get:

$$\text{Ln Transmission} = K_1 - NK_2$$

The logarithm of the transmission is thus linearly proportional to the particulate concentration.

TRANSMISSOMETER ACCURACY

Accuracy of the transmissometer measurements are mainly controlled by particle concentration, instrument pathlength, and instrument calibration. We have seen that $T(z) = e^{-cz}$. If cz is large, T(z) is small and problems will be encountered with signal-to-noise ratio. When cz is small, T(z) is large where accuracy is limited by the stability and calibration of the instrument. For these reasons the instrument is most accurate when the magnitude of cz is such that T(z) falls somewhere between 95% and 1 %. In turbid water valid measurements can readily be made at much lower light levels than !% (photodiodes are linear over several orders of magnitude), but then the instrument rapidly becomes insensitive to changes in particle concentration when light transmission decreases below 1%. In clean water ($\%T \geq 95\%$), where small changes in transmission must be measured, careful calibration of the transmissometer and high-accuracy recording equipment is required. These points are demonstrated by the data in Table 1.

Calibration data from the laboratory and field experiment in Table I shows that the ratio of beam attenuation coefficient to total suspended mass for these two data sets is approximately $1 m^{-1}$/mg/l. This corresponds to field values ($c_p \approx 0.1 m^{-1}$ for 100 µg/l) obtained by Peterson [1977]. So in the following examples related to sensitivity and dynamic range, we will assume $c_p = 1\ m^{-1}$ for a total suspended mass concentration of 1 mg/l. The user should be aware that this ratio of beam attenuation coefficient to total suspended mass must be determined experimentally since it is a function of particle size distribution, particle shape distribution, particle refractive index and wavelength.

A calibration diagram of specific beam attenuation has been developed by Spinrad [1986] and can be used when the correlation between the beam attenuation coefficient and suspended mass cannot be determined experimentally. With a priori estimates of the shape of the particle size distribution and particle composition (i.e., refractive index and density) it is possible to predict the ratio of beam attenuation coefficient to suspended mass. A reprint of Spinrad [1986] is included for reference and can be found in the back flap of this manual.

CALIBRATION DATA FROM A LABORATORY AND FIELD EXPERIMENT

HEBBLE PROJECT

TSM (mg/l)	C (m^{-1})	T (1m)	T (25cm)	T (10cm)	T (5cm)
0.001	.401	.6697	.9046	.9607	.9801
0.005	.404	.6676	.9039	.9604	.9800
0.01	.409	.6643	.9028	.9599	.9798
0.05	.444	.6415	.8949	.9566	.9780
0.10	.488	.6139	.8851	.9524	.9759
0.25	.620	.5379	.8564	.9399	.9695
0.50	.840	.4317	.8106	.9194	.9589
1.0	1.28	.2780	.7261	.8799	.9380
2.5	2.60	.0743	.5220	.7711	.8781
5	4.80	.0082	.3012	.6188	.7866
10	9.2	.0001	.1003	.3985	.6313
25	22.4	0	.0037	.1065	.3263
50	44.4	0	0	.0118	.1086
100	88.4	0	0	.0001	.0120
250	220.4	0	0	0	0
		DIATOMACEOUS EARTH			
0.001	.400	.6307	.9098	.9608	.9802
0.005	.402	.6690	.9044	.9606	.9801
0.01	.404	.6676	.9039	.9604	.9800
0.05	.419	.6577	.9005	.9590	.9793
0.10	.437	.6460	.8965	.9572	.9784
0.25	.490	.6126	.8847	.9522	.9758
0.50	.585	.5571	.8639	.9432	.9712
1.0	.770	.4630	.8249	.9259	.9622
2.5	1.33	.2645	.7171	.8755	.9357
5	2.25	.1054	.5698	.7985	.8936
10	4.10	.0166	.3589	.6637	.8146
25	9.65	0	.0896	.3810	.6172
50	18.9	0	.0089	.1511	.3887
100	37.4	0	0	.0238	.1541
250	92.9	0	0	0	.0096

TABLE 1

SENSITIVITY

The sensitivity of the 10 cm transmissometer to changes in suspended mass for both clean and turbid water conditions is shown in the following examples. For these examples it will be assumed that the smallest change in transmission that can be measured by the users equipment is 0.1%. It should be noted here that the transmissometer noise level is approximately 0.01% so with a high resolution data acquisition system more precise measurements are possible than given in these examples.

CLEAN WATER EXAMPLE - In clean water, the change in the beam attenuation coefficient, Δc for a 0.1% change in transmission is:

$$\Delta c = 10 \ln(.963) - 10 \ln(.964) \approx 0.010 \ m^{-1}$$

Since we assumed the specific beam attenuation for these examples would be 1 m^{-1}/mg/l then:

$$\textit{CLEAN WATER SENSITIVITY} = (0.010 \ m^{-1})/(1 \ m^{-1}/mg/l) = 0.010 \ mg/l$$

So in clean water an increase of 0.010 mg/l in suspended mass results in a decrease of 0.1% in transmission for a 10 cm pathlength.

TURBID WATER EXAMPLE - In turbid water, the change in the beam attenuation coefficient, Δc for a 0.1% change in transmission is:

$$\Delta c = 10 \ln(.009) - 10 \ln(.01) \approx 1.05 \ m^{-1}$$

Since we assumed the specific beam attenuation for these examples would be 1 m^{-1}/mg/l then:

$$\textit{TURBID WATER SENSITIVITY} = (1.05 \ m^{-1})/(1 \ m^{-1}/mg/l) = 1.05 \ mg/l$$

So in turbid water an increase of 1.05 mg/l in suspended mass results in a decrease of 0.1% in transmission for a 10 cm pathlength.

DYNAMIC RANGE

The range over which measurements of suspended mass can be measured accurately is dependant on the optical properties of the suspended particles and the pathlength of the transmissometer. We have already determined in the clean water example above, the minimum value of suspended mass that can be measured with a 10 cm transmissometer. To determine dynamic range a lower limit of 1% transmission in a 10 cm pathlength for turbid water is assumed. Then the maximum value in terms of suspended mass can be determined since:

$$T = e^{-cz} \quad \text{or} \quad (\text{Ln } T)/z = -c$$

Where T= 0.01 and z=0.10 m

$$[\text{Ln}(0.01)]/0.10 = -c = 46 \ \text{m}^{-1}$$

Since 1 mg/l corresponds to $c = 1 \ m^{-1}$, within an order of magnitude depending on the nature of the particles, then $c = 46 \ m^{-1}$ shows that the maximum value of suspended mass that can be measured accurately with the 10 cm transmissometer is 46 mg/l. We have shown that in clear water, a 0.1% change in transmission corresponds to 0.010 mg/l and that in turbid water 1% transmission is approximately 46 mg/l, thus the 10 cm transmissometer is ideally suited for measuring naturally occurring particle suspensions from 0.01 mg/l to 46 mg/l.

TRANSMISSOMETER DESIGN

The transmissometer is shown on page 3, the outline drawing. The pressure housing is constructed from plastic, (Celcon) to eliminate problems with corrosion. A collimated light source and optical receiver are located 10 cm apart and are connected by three stainless steel rods. Optical alignment is accomplished by adjusting the length of each connecting rod. Input power and output signals are fed through a four-pin marine connector located at the top of the pressure housing. The plastic surfaces adjacent to the light path can be painted with anti-fouling paint to prevent blocking of the light path by marine growth.

Optical design of the collimated light source is very simple; it consists of a window, aperture stop, achromatic lens, pinhole and LED. The lens has a focal length of 60mm and is 23 mm in diameter. An LED and a temperature sensing diode are positioned at the lens focal point in back of the pinhole to collimate the light source. Characteristics of the FFE-3100 LED light source are: light source diameter = 125µm; peak wavelength = 670 nm and spectral line width = 40 nm. The resultant light source beam parameters are: Beam diameter = 15 mm; beam divergence = 0.15 degrees; radiated output power = 3 x 10^{-7} watt.

The optical receiver consists of a lens, 23 mm in diameter and focal length of 60 mm with a silicon photovoltaic detector located at the focal point of the lens. The detector is potted into a threaded assembly to enable alignment of the detector. The detector used is an E.G.&G. UVI00BQ and has the following characteristics: active area = 5.1mm^2; spectral range, 350-1150 nm; and response at 670 nm, 0.33 amps/watt. Receiver parameters are: aperture = 20 mm and acceptance angle is less than 1 degree in water.

The transmissometer electronics, shown schematically in figure 3, supplies regulated power, generates a modulated temperature compensated drive voltage to the LED, and synchronously detects the amplified detector signal. The circuit board layout is shown in figure 4 and the parts are listed on page 9.

Power requirements for the transmissometer are 9 to 15 VDC at approximately 10 milliamperes, which is normally supplied by a 12 VDC battery or equivalent power supply. Power is fed through a blocking diode DI to prevent damage to circuitry in case reverse polarity is applied to power terminals. The +7.5V regulated supply consists of FET - Q1, operational amplifier - A2A, a 2.5 VDC reference - VR and resistors - R1 and R2. An astable multivibrator IC1, in conjunction with FET switch - IC2 and the diode rectifier filter (D2, D3,.C5, C6) generate a negative voltage which is regulated to -2.5 VDC by A2B, R3, and R4.

LED drive is supplied by A1B through R13. The input signal to A1B is the sum of the +2.5 VDC reference voltage (VR) and the negative output from the temperature compensation circuit A1A, D5, R6. The resistor divider ratio of R7, R8 and R9 is adjusted to temperature compensate the radiated output power of the LED. Modulation of the LED output is accomplished by switching the gain of A1B with a FET switch in IC2.

The detector output current is amplified by the current to voltage converter -A3A, R14, C7, and then A.C. coupled by capacitor C8 to remove any D.C. component in the received signal caused by ambient light incident on the detector. Amplifiers A4B and A4A then produce "0" degree phase and "180" degree phase signals which are synchronously detected by a SPDT FET switch in IC2. The output from the synchronous detector is then amplified and filtered by A3B, R21, R22, R23, R24, and C9. The output voltage from A3B is calibrated by R24 so that 0 to 5 VDC corresponds to 0 to 100% transmission in water.

CALIBRATION

Calibration of the transmissometer at the factory includes alignment, temperature compensation, and adjustment of the receiver gain to obtain an output voltage corresponding to 96.4 % transmission in filtered distilled water.

Alignment in air is achieved by first collimating the light source so that the transmitted beam at 10 cm is 15 mm in diameter and is centered on the receiver lens; the detector is aligned next to obtain maximum output. After the light source and optical receiver have been aligned, R17 is selected to obtain 1 VDC at pin 14 of IC2. The transmissometer is then installed in a temperature control chamber, and with R7 and R12 set in the middle of their range, temperature is cycled between 0 degrees and 25 degrees centigrade. R7 and R12 are then adjusted to temperature compensate the transmissometer.

After the transmissometer has been aligned and temperature compensated, it is immersed in filtered distilled water. The transmission of this water is 69.5% as measured by a 1m beam transmissometer. We then convert from transmission readings on the 1m transmissometer, T(1m), to readings on the 10 cm transmissometer, T(0.10m). Since: $T(1m) = e^{-c}$, $c = LnT(1m)$; and hence: $T(0.10m) = e^{(0.10)LnT(1m)}$.

A reading of 69.5% transmission on the 1m beam transmissometer is found by means of the equation above to correspond to a 96.4% transmission on the 10 cm transmissometer. With the instrument in water as described above, the receiver gain, R24, is set so that the output voltage is 4.820 VDC which, for this transmissometer, corresponds to 96.4% transmission in water. The unit is then removed from water and the voltage reading in air is recorded. This air calibration can then be used to compensate for any future change in LED output as described in the transmissometer operating instructions on page 4.

The calibration of an optical instrument in terms of volume or weight of suspended matter must be done experimentally. The attenuation properties of a collection of particles depends on their size, shape, and index of refraction structure. The relationship between observed attenuation and particle volume or weight thus changes somewhat as the location of the observation changes. Nevertheless, it has been shown that the correlation coefficient between attenuation and suspended volume is .80 to .95 in the surface layer and .90 to .98 below the thermocline. The high correlation indicates that the particle properties do not change a great deal in distances of about 50 miles or in periods of weeks. The exceptions are active phytoplankton blooms, in this case the correlation can be as low as 0.70.

DATA INTERPRETATION

Conversion of the transmissometer data from volts direct current, VDC to percent transmission, %T is simply %T = 20 times VDC. See the transmissometer operating instructions for the air-calibration corrections. Conversion from %T to c, the beam attenuation coefficient for a 10 cm transmissometer is, c = - 10 ln(T) where T = %T/100.

Part of the error in a transmission measurement is due to the inclusion of forward scattered light. If $\beta(\theta)$ is the volume scattering function and γ is the half angle of the receiver, the attenuation coefficient will be underestimated by:

$$g = 2\pi\int_0^{\gamma} \beta(\theta) \sin\theta \, d\theta$$

where the lower integration limit is 0 and the upper limit is γ. The measured transmission will then be overestimated by a factor of e^{-g}. In this transmissometer, $\gamma = 1$ degrees. The volume scattering function for angles less than 1 degree is nearly flat as predicted by Mie theory. We can thus integrate $\beta(\theta)$ to obtain g as shown on Table 2. Table 2 also shows what the beam attenuation coefficient is for a given near forward scattering error when the slope of the hyperbolic particle size distribution is 4.0 and the index of refraction is 1.20. For different types of particles, the beam attenuation will be different, but of the same order of magnitude. It is thus possible to correct for the finite half angle of the receiver if either the forward scattering is known or if the nature of the particles is known. If neither is known one can use the results in Table 2 as representing resuspended sediments or suspensions of terriginous origins. The error due to this effect is always in the same direction as the amount of light received is always larger than it should be. Applying an average correction is thus better than applying no correction at all.

TABLE 2

10 cm Transmissometer attenuation coefficients corrected for scattering errors. The scattering errors are computed from MIE tables. Particles are assumed to have an average index of 1.20 and a size distribution described by

$$dN = N_0 D^{-4} dD$$

Measured Tr (%)	96.27	96.09	90.57	61.1	37.4	13.9	1.94
Computed c (m^{-1})	.3798	.3994	.990	4.92	9.84	19.7	39.4
Scattering error (m^{-1})	.0002	.0006	.010	.08	.16	.3	.6
Actual c (m^{-1})	.3800	.4000	1.00	5.00	10.00	20.0	40.0

NOTES ON INTERFACING THE TRANSMISSOMETER TO YOUR SYSTEM

High resolution measurements can be obtained with the transmissometer if your data acquisition system has a low noise analog to digital converter (ADC). Most ADC's used in systems are designed to make measurements rapidly. Acquiring data with these converters can present problems with noisy data. Two solutions for this problem normally implemented are one, the sensor output is fed through a low pass filter and the second is to average several data samples. Another solution would be to use an integrating converter. From a low noise standpoint this approach is much more acceptable, especially if the integration time is 16.6 milliseconds so that interference from 60 cycle line power is canceled. Data can be obtained from the transmissometer with better than 14 bit resolution, 0.006%, using an integrating converter without a low pass filter or averaging samples. Needless to say the integrating converter is recommended for recording transmissometer data.

Accuracy of the ADC must be considered also. 12 bit accuracy is normally quoted by the manufacturers of recording equipment but this is normally for an input of +/- 10 VDC. The output of the transmissometer is 0-5 VDC. Using this converter for measuring the transmissometer output would result in 10 bit, 0.1% accuracy since only 1/4 of the range of the converter is being used. To solve this problem a converter should be chosen that has a 0-5 VDC input for full scale output. Accuracy of the converter is mainly controlled by the temperature stability of its reference and since temperature can vary over a large range, (the hot deck of a ship to near freezing in arctic waters) particular attention to the reference element used in the ADC is essential to obtain high accuracy recording of transmissometer data.

Response time or time constant of the instrument is 0.1 second. The instrument requires at least 3 seconds warm up time before the output data can be considered valid. The instrument has been temperature compensated over the range of 0 to 25 degrees centigrade, but some hysteresis between up and down cast can be expected if the instrument is hot on the deck of a ship and then immersed in cold water. To avoid this problem the instrument can be cooled on deck with running water or allowed to stabilize at the surface of the water before a cast is made.

Accurate data acquisition with the transmissometer can only be accomplished if strict attention is paid to the procedures outlined on page 4, the transmissometer operating instructions, i.e. clean the windows and pay attention to the air calibration.